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INFLUENCE OF WATER DEPTH ON TRACTION CHARACTERISTICS OF ASPHALT CONCRETE PAVEMENTS

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An investigation was conducted on taxiway 2 at the Albuquerque International Airport, Kirtland Air Force Base to study the influence of various amounts of water (0.05, 0.10, 0.20, and 0.30 in.) on the traction characteristics of an asphalt concrete pavement. Both the Mu-Meter and the diagonally braked vehicle (DBV) were used in this investigation. Correlations between coefficient of friction and time after wetting parametricized with respect to water depth and correlations between stopping distance ratio (SDR) and time after wetting were determined. The coefficient of friction, measured by the Mu-Meter within (over)

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ABSTRACT (Cont'd)

the DBV strip, versus SDR, measured by the DBV, showed a fair degree of departure from the theoretical relationship of SDR versus calculated coefficient of friction. Invariably, the data indicated that for a given SDR the measured coefficient of friction displayed a fair degree of dispersion and generally was greater than the theoretical prediction. The repeatability of the Mu-Meter data was assessed by performing spot checks and comparing the results obtained at two different times during the testing. The need to develop a more accurate system to measure water depth is strongly emphasized.

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ILLUSTRATIONS (Concl'd)

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ABBREVIATIONS AND SYMBOLS

CSD	corrected stopping distance (adjusted to 60 mph initial velocity)
DBV	diagonally braked vehicle
DSD	dry stopping distance
NASA	National Aeronautics and Space Administration
RSD	raw stopping distance
SD	stopping distance
SDR	stopping distance ratio
V	initial velocity of DBV
W	weight of DBV
g	gravitational constant
t_1	zero reference time; average clock time between entrance and exit times of water truck on test area when water was applied in one pass
t_2	zero reference time; average clock time between entrance and exit times of water truck on test area during second pass when water was applied in two passes
t_3	zero reference time; average clock time between entrance time of first pass and exit time of second pass of water truck on test area when water was applied in two passes
Δt_1	elapsed time after wetting when water was applied in one pass
Δt_2, Δt_3	elapsed time after wetting when water was applied in two passes
μ_c	coefficient of friction calculated from DBV data
μ_d	dry coefficient of friction
μ_m	coefficient of friction as measured by the Mu-Meter

SECTION I
INTRODUCTION

An investigation was conducted on Taxiway 2 at the Albuquerque International Airport, Kirtland Air Force Base, to study the influence of various water depths on the traction characteristics of an asphalt concrete pavement. The artificially simulated wet conditions consisted of applying 0.05, 0.10, 0.20 and 0.30 in. of water to the pavement. The primary objectives of this investigation were as follows:

(1) to determine a relationship between coefficient of friction measured with the Mu-Meter, μ_m, and time after wetting for various amounts of applied water,

(2) to determine a relationship between stopping distance ratio (SDR), measured with the diagonally braked vehicle (DBV), and time after wetting for various amounts of applied water,

(3) to investigate the existence of a correlation between the SDR associated with the DBV and average coeffi. . . of friction measured by the Mu-Meter, and

(4) to investigate the possibilities of improving the AFWL standard skid resistance test procedure.

The field testing program was conducted with the cooperation of the Air Force Weapons Laboratory, Kirtland Base Operations, and the Kirtland Air Force Base Fire Department. Taxiway 2 was selected because of its length and the limited traffic on this portion of the airfield.

SECTION II
TEST AREA

Figure 1 shows the overall dimensions of the test area, including the DBV test strip and the location of the water-depth measurement stations. This test area was located in the center portion of the taxiway so that approximately 1,200 ft of the taxiway would be available east and west of the test area for acceleration and deceleration of the test vehicles. The test area, which was constructed of asphalt concrete, had a one-way cross slope. The cross-slope measurements obtained along the longitudinal axis at 100-ft intervals from the east (26) end of the test area are given in table I. These measurements were obtained with a cross-slope measuring device* developed for rapid and accurate cross-slope measurement of runway surfaces.

*The cross-slope measuring device was developed by Mr. E. R. Hargett at the Eric H. Wang Civil Engineering Research Facility.

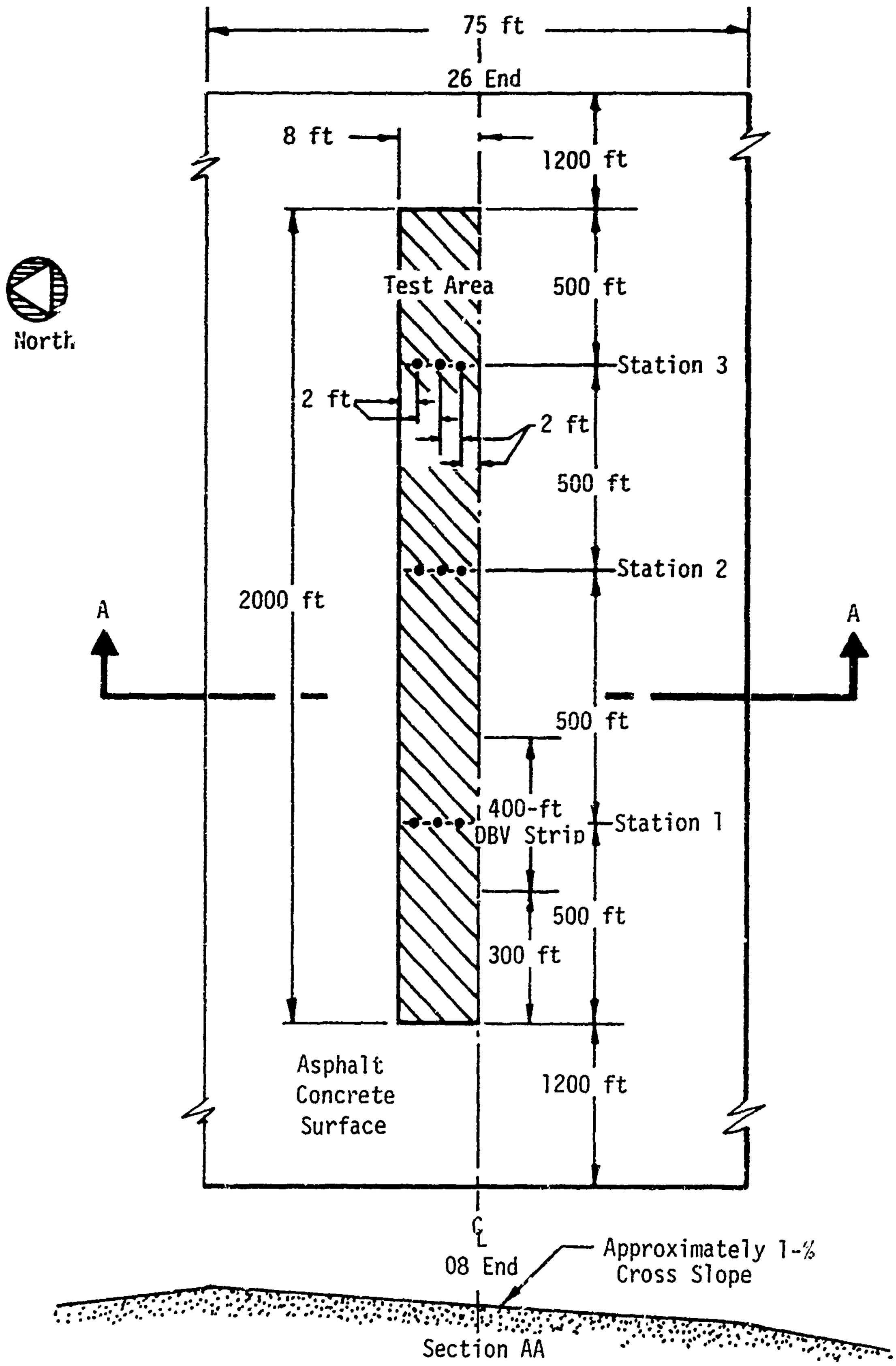

Figure 1. Taxiway 2 Test Area

Table I

AVERAGE CROSS SLOPES OF TEST AREA

Distance from East End of Test Area, ft	Slope, %
0	0.6
100	1.1
200	1.6
300	1.0
400	0.7
500	0.8
600	1.1
700	1.5
800	1.3
900	1.3
1000	1.8
1100	1.8
1200	1.8
1300	1.8
1400	1.0
1500	1.8
1600	1.8
1700	1.8
1800	1.0
1900	0.7
2000	1.8

Note: Measurements were taken across a 10-ft span at the centerline of the taxiway.

SECTION III
TEST EQUIPMENT

The equipment for field testing consisted of a water truck for surface watering, a Mu-Meter and a towing vehicle, a DBV, a cross-slope measuring device, and several NASA water-film depth gages.

1. WATER TRUCK

A 50,000-gal. F-6 foam truck was used to wet the surface of the test area. The truck was equipped with an 8-ft spray bar, and a tachometer for speed control. At a pump pressure of 100 psi, water was discharged at a rate of 3.05 gal./sec. The truck was calibrated to discharge 1,000 gal. of water over the 8- x 2,000-ft test area (0.10-in. water depth) when operated in second gear at 1,525 rpm (1,000 gal. in 5 min 28 sec). Application rates for the various water depths used in this investigation are given in table II.

Table II

WATER TRUCK CALIBRATION DATA

Water Depth, in.	Total Amount of Water Applied to 8- x 2000-ft Test Area, gal.	Discharge Time, min:sec
0.025	250	1:22
0.050	500	2:44
0.100	1000	5:28
0.150	1500	8:12
0.200	2000	10:56
0.300	3000	16:24

2. MU-METER

The Mu-Meter (fig. 2) is a small friction-measuring trailer manufactured by M. L. Aviation, Maidenhead, Berks, England. This trailer, which is towed by a standard pickup truck, continuously measures the coefficient of friction of the pavement surface over which it is towed. The friction-sensing mechanism in the trailer consists of two rolling wheels inclined at 7.5° from the longitudinal axis of the trailer. The principal components of the Mu-Meter are shown in figure 3. The Mu-Meter physically measures the side-slip force between the tires and the pavement surface; this force is registered on a load-sensing cell located between the two hinged arms of the trailer frame. When the side-slip force is divided at the normal load acting on the wheels of the Mu-Meter a continuous record of the coefficient of friction of the pavement surface is registered by a continuous-recording device. The trailer is also equipped with instrumentation that integrates the coefficient of friction versus distance. Thus, an average coefficient of friction between any two given points of the pavement surface may be obtained. The Mu-Meter is normally operated with 10-psi tire pressure at a constant speed of 40 mph. (This is above the theoretical hydroplaning speed of the test vehicle on wet pavement.)

3. DIAGONALLY BRAKED VEHICLE

The DBV is a specially designed and instrumented vehicle developed to evaluate the traction characteristics of runway surfaces. The DBV concept was developed by NASA in conjunction with the Combat Traction Program. The test vehicle used in this investigation (fig. 4) consisted of a conventional station wagon equipped with a modified braking system and special equipment to measure stopping distance, velocity, deceleration, and brake pressure. The braking system was modified so that two diagonally opposite wheels are simultaneously braked, while the other two wheels are left free rolling for directional control. A fifth wheel (a 26- x 2.125-in. bicycle rim and tire) is used to measure stopping distance and velocity. Under a diagonally braked configuration, the distance required to stop the vehicle from an initial velocity of 60 mph is measured by this fifth wheel. The data are recorded on a

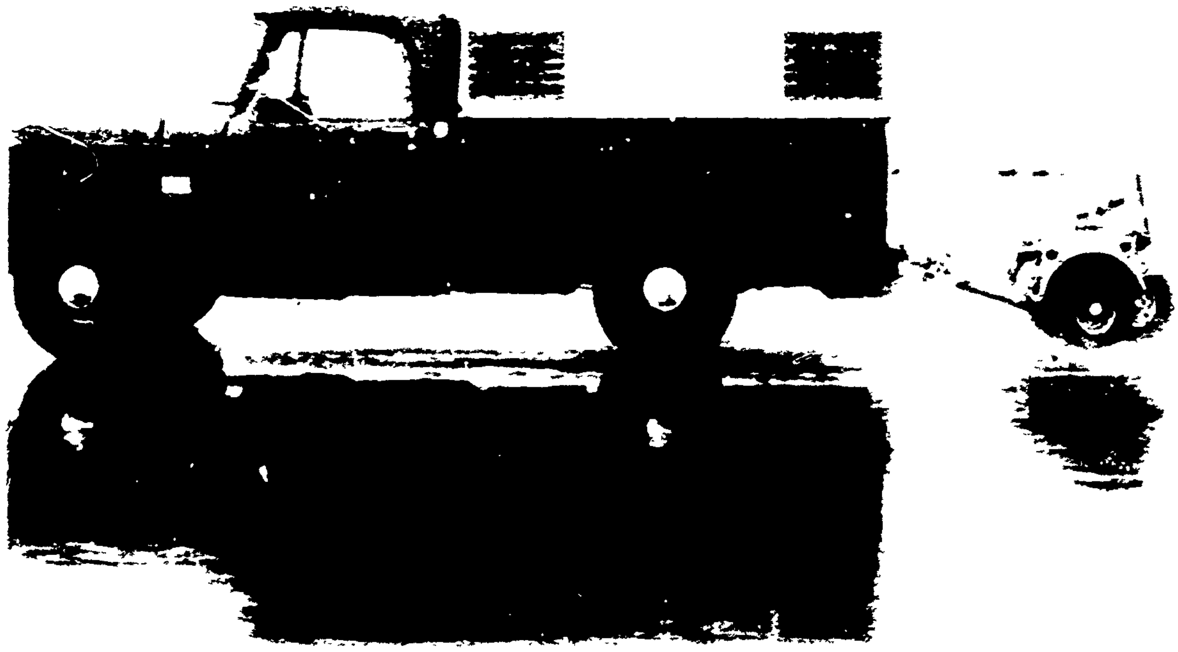

Figure 2. Mu-Meter

four-channel analog strip recorder equipped with a heated stylus. A four-channel calibration and gage conditioning panel programs the data on the strip recorder. Two deceleration-versus-distance and one brake pressure-versus-distance traces are recorded; the fourth channel was not utilized. A pulse generator driven by the axle of the fifth wheel furnishes pulse inputs for initial velocity (at the instant of brake application) and stopping distance measurements. Both initial velocity and stopping distance are displayed on a digital readout.

4. CROSS-SLOPE MEASURING DEVICE

The cross-slope measuring device (fig. 5) is made of a rectangular bar of aluminum, 5/8 x 2-1/2 in. in cross section and 10 ft long. Five machinist's levels are attached to the bar to define slopes of 0.0, 0.5, 1.0, 1.5, and 2.0 percent. This CERF device was designed and built to rapidly measure the cross slopes of runway surfaces. These data are primarily used to evaluate the drainage characteristics of the pavement surface. In this investigation, the device was used to measure transverse gradients at 100-ft intervals along the test area.

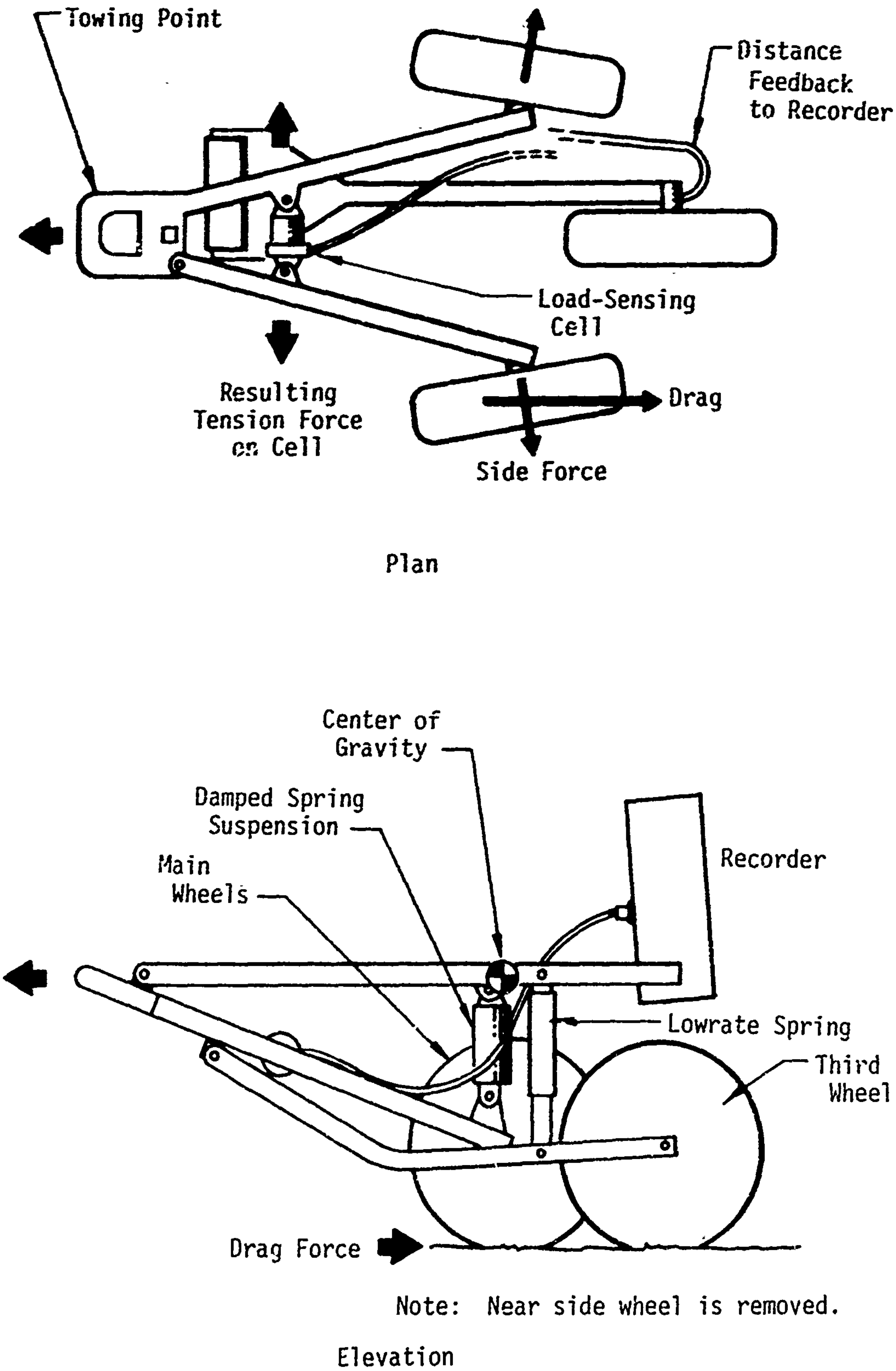

Figure 3. Mu-Meter Components

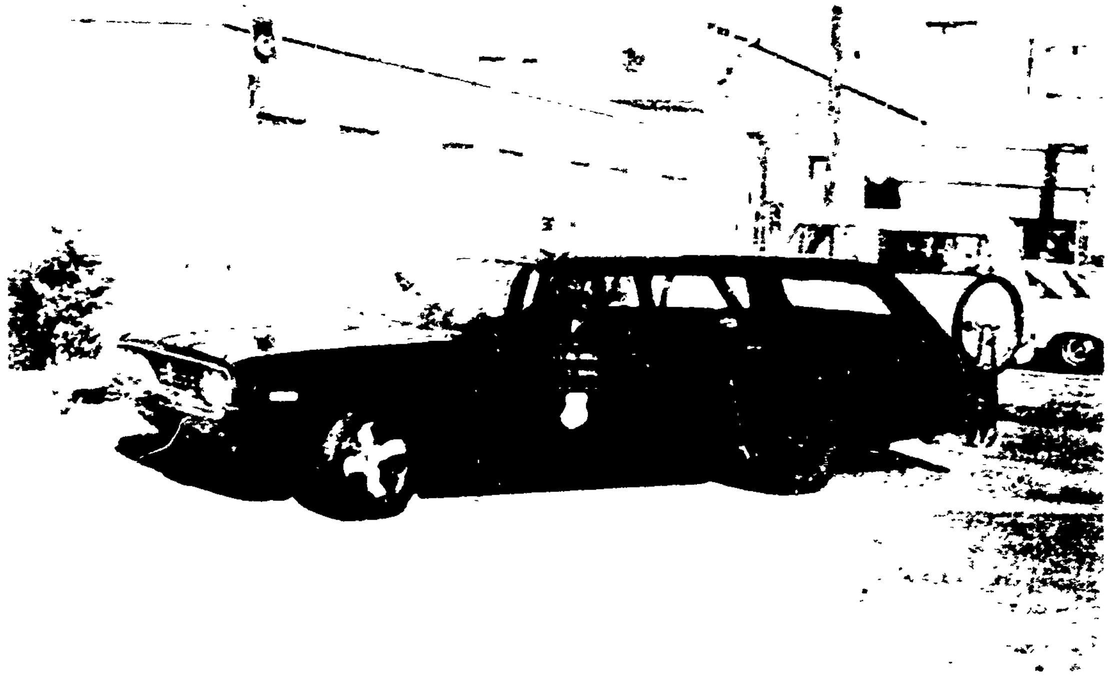

Figure 4 Diagonally Braked Vehicle

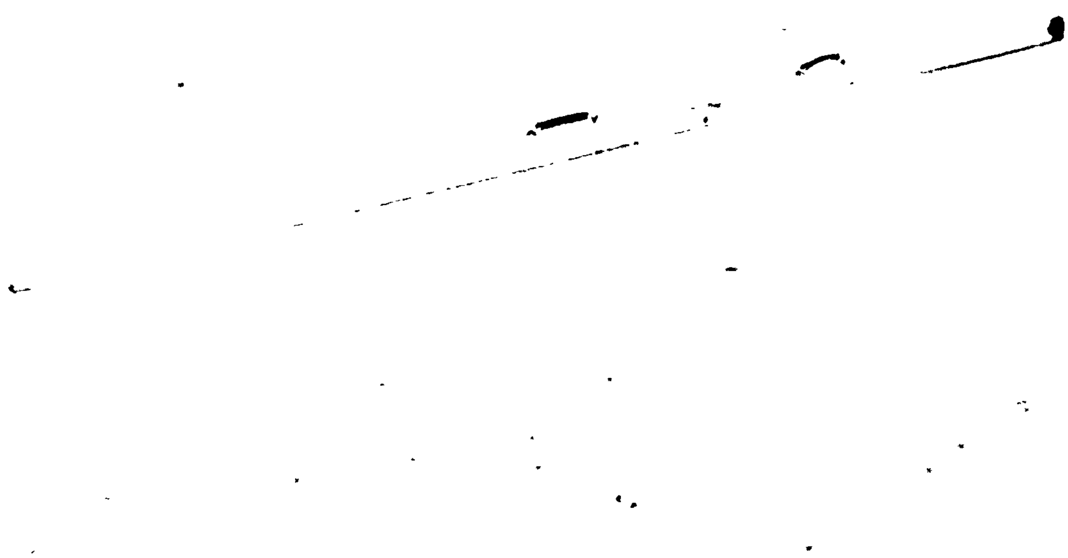

Figure 5. Cross-Slope Measuring Device

5. WATER-FILM DEPTH GAGE

The water-film depth gage used in this study (fig. 6) was developed by NASA to rapidly measure water-film depth on highway and airfield pavement surfaces. This water-film depth gage consists of a plastic disc 5 in. in diameter supported by three metal prongs 15/16 in. long. Plexiglas rods of different lengths are attached to the bottom side of the circular plastic disc. These rods are adjusted so that their tips are located between 0.01 and 0.10 in. above the plane defined by the tips of the metal prongs. The upper tips of the Plexiglas rods are marked to indicate the actual gap between the plane passing through the tips of the prongs and the bottom of each individual rod. Since water is a light-reflecting substance, it reflects more light than the runway surface and, consequently, the tips of the rods that are not in contact with the water appear lighter than those that are touching or submerged in the water. From the rods that appear dark, the one that has the highest reading on the scale determines the water-film depth at that particular location. For instance, in figure 6 the water depth is approximately 0.06 in.

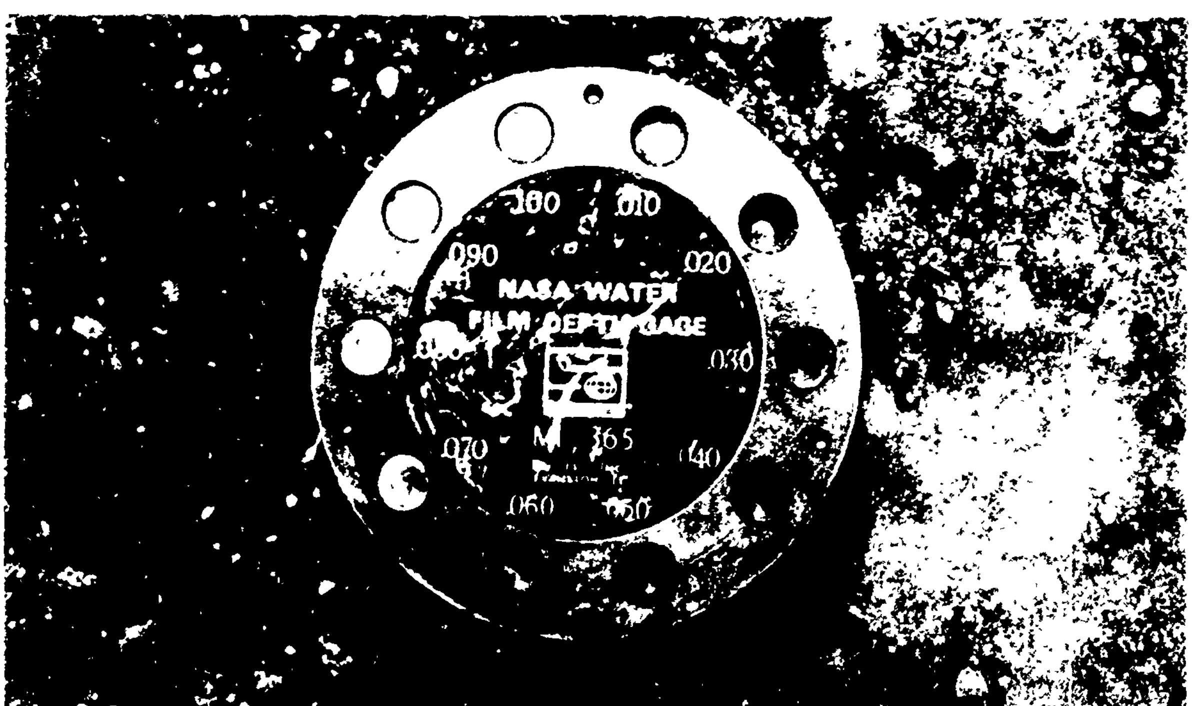

Figure 6. NASA Water-Film Depth Gage

SECTION IV
TEST PROCEDURES

The test program consisted of Mu-Meter measurements of pavement friction and DBV stopping distance measurements under both dry conditions and four selected water depths each applied in both one and two passes. The time of each test operation was recorded so as to establish time intervals after wetting. Water-depth measurements were obtained with the NASA water-film depth gage at three locations within the test area in order to study the dissipation of water from the pavement surface with respect to time after wetting. The basic test operations were as follows:

(1) Water was applied from the water truck to the test area at the rates required to yield water depths of 0.05, 0.10, 0.20, and 0.30 in. on the test surface. (See table II.) These four water volumes were applied in both one and two passes. One half of the total amount of water required was applied on each pass for the two-pass application. This constituted eight test variables in pavement wetness (i.e., eight test conditions).

(2) Mu-Meter measurements of pavement friction and DBV stopping-distance measurements were made for each of the eight test conditions of pavement wetness.

(3) Water-depth measurements were made immediately after each vehicle passed through each water-measurement station.

(4) A series of Mu-Meter readings and DBV stopping-distance measurements for a dry pavement condition were made. These measurements were necessary in order to evaluate the recovery rate of the coefficient of friction and to compute SDRs for the various conditions of pavement wetness.

SECTION V
FIELD TEST DATA

The data obtained from testing the pavement surface under the eight different conditions of pavement wetness are given in appendix I. These data consist of coefficients of friction and SDRs for various time intervals after wetting for each test. Appendix I also furnishes average coefficients of friction for the entire 2000-ft test area as well as average coefficients of friction for that portion of the test area within which SDR measurements were made using the DBV. The elapsed time data for both the DBV and Mu-Meter tests are the average time readings when either the DBV was midway into the DBV test strip or the Mu-Meter was midway into the 2000-ft-long test area. The elapsed time when the Mu-Meter was traversing the DBV portion of the test area was not recorded. However, these times can be calculated since the Mu-Meter maintained a constant speed of 40 mph.

Water-depth measurements were taken at stations 1, 2, and 3; however, dependable time records were obtained at station 1 only. Consequently, appendix II contains only the water-depth data for station 1.

Coefficients of friction and DBV stopping distances for a dry condition of the pavement surface were periodically measured throughout the test program. As shown in table III, 14 Mu-Meter dry runs were conducted on the entire test area; however, in only 10 of these records of the average dry coefficients

Table III

SUMMARY OF DRY-RUN DATA

Number of Runs	Coefficient of Friction						Average Stopping Distance, ft
	Entire Test Area			DBV Test Strip			
	Min.	Avg.	Max.	Min.	Avg.	Max.	
14	0.79	0.81	0.83	--	--	--	--
10	--	--	--	0.78	0.80	0.82	--
4	--	--	--	--	--	--	336

of friction within the DBV portion of the test area were obtained. Four dry runs were conducted with the DBV to obtain the dry stopping distance. These data indicate that the DBV test strip did not possess as good traction characteristics as did the overall 2000-ft test area. The average dry stopping distance of 336 ft (variations from the average were insignificant) was utilized in all the SDR calculations in appendix I.

SECTION VI
DATA ANALYSIS

The data collected during this investigation were analyzed to determine the following:

1. The influence of various water application rates on the skid resistance properties as measured by the Mu-Meter and DBV.

2. The influence of water depth on the coefficient of friction and stopping distance ratio.

3. To investigate the possibility of improving the standard AFWL test procedure for the skid resistance evaluation of wet runways.

In these analyses, several methods to compute the time after wetting were used. Throughout the report three basic time designations are used. When the water was applied to the test section in a single pass, the zero water time was the average time (clock time) that the water truck was applying water (entrance to exit of the truck). This time is hereafter designated t_1.

For those test sections where the total water volume was applied in two equal applications, the zero water time was computed as follows:

t_2 = average clock time of the second water application (entrance to exit times)

t_3 = average clock time for the entire wetting operation (entrance of first wetting pass to exit of second pass)

The time after wetting for any measurement made by the test vehicles is referred to as Δt_1, Δt_2, or Δt_3. The designation symbol depends upon the method used to compute the zero water time.

1. COEFFICIENT OF FRICTION RECOVERY

Although the general trend displayed by the friction recovery curve is not influenced by the assumption pertaining to zero reference time, the position of the recovery curve is shifted with respect to the time axis for the various methods of zero reference time interpretation.

The recovery of the coefficient of friction versus time after wetting interpreted according to the three methods described above (i.e., time intervals Δt_1, Δt_2, and Δt_3) for both single- and double-pass applications of a 0.05-inch water depth is shown in figure 7; similar plots for 0.10-, 0.20-, and 0.30-inch water depths applied in one and two passes are given in figures 8, 9, and 10, respectively.

Examination of figures 7 through 10 reveals that for any given water depth, the single-pass application invariably creates the worst traction characteristics early after wetting (within 15 minutes). However, for any given amount of applied water the double-pass application does not yield radically different friction-recovery characteristics provided that the elapsed time after wetting is interpreted according to time interval Δt_3. These figures clearly indicate that for double-pass application of any given water depth, interpretation of the elapsed time after wetting according to time interval Δt_2 causes the shifting of the friction-recovery curve too far to the left, thus yielding high coefficients of friction at relatively early times. At late times (in excess of 15 minutes), all three methods of zero reference time interpretation yield comparable data which in general lie within the domain of the experimental data spread.

The reason a given amount of water was applied in two passes was as follows. It was assumed that the first half of the water would fill the pores and irregularities in the pavement surface, while the second half would provide as much free-floating water as possible to create an adverse pavement traction condition. As can be seen in figures 7 through 10, the time interval between water application and the initial vehicular measurement is a minimum when Δt_2 is used as the elapsed time. However figuest 7 through 10 also show that the first data point for a single wetting pass, Δt_1, or for double application using Δt as the elapsed time interval is at least 7 minutes after wetting. While it is not the intent to arbitrarily pick a method of computing a zero water reference time that will allow a small time interval after wetting, a method is necessary that does not require extrapolation of the data for long time intervals; therefore, the various application rates and time calculations were analyzed to see if a more severe wet condition could be obtained for use in the standard AFWL test procedure. To p tray the influence of the recovery rate of the coefficient of friction as a function of applied water depth, the data from figures 7 through 10 were rearranged for one a and two pass applications in figures 11 and 12 respectively.

It can be noted on figures 11 and 12 that the initial coefficient of friction measured by the Mu-Meter is essentially the same regardless of wetting technique or method of calculating the zero water time. The data confirm the difference in recovery rates (improved friction) for the various water volumes applied. The more water applied the longer the drainage period for a return to a dry condition. However, the data is insufficient to conclude that if 0.30 inch of water is applied the recovery curve can be extrapolated back to the 3 minute point, which is currently the first data point in the standard AFWL skid resistance test. It should also be pointed out that unless two water trucks are

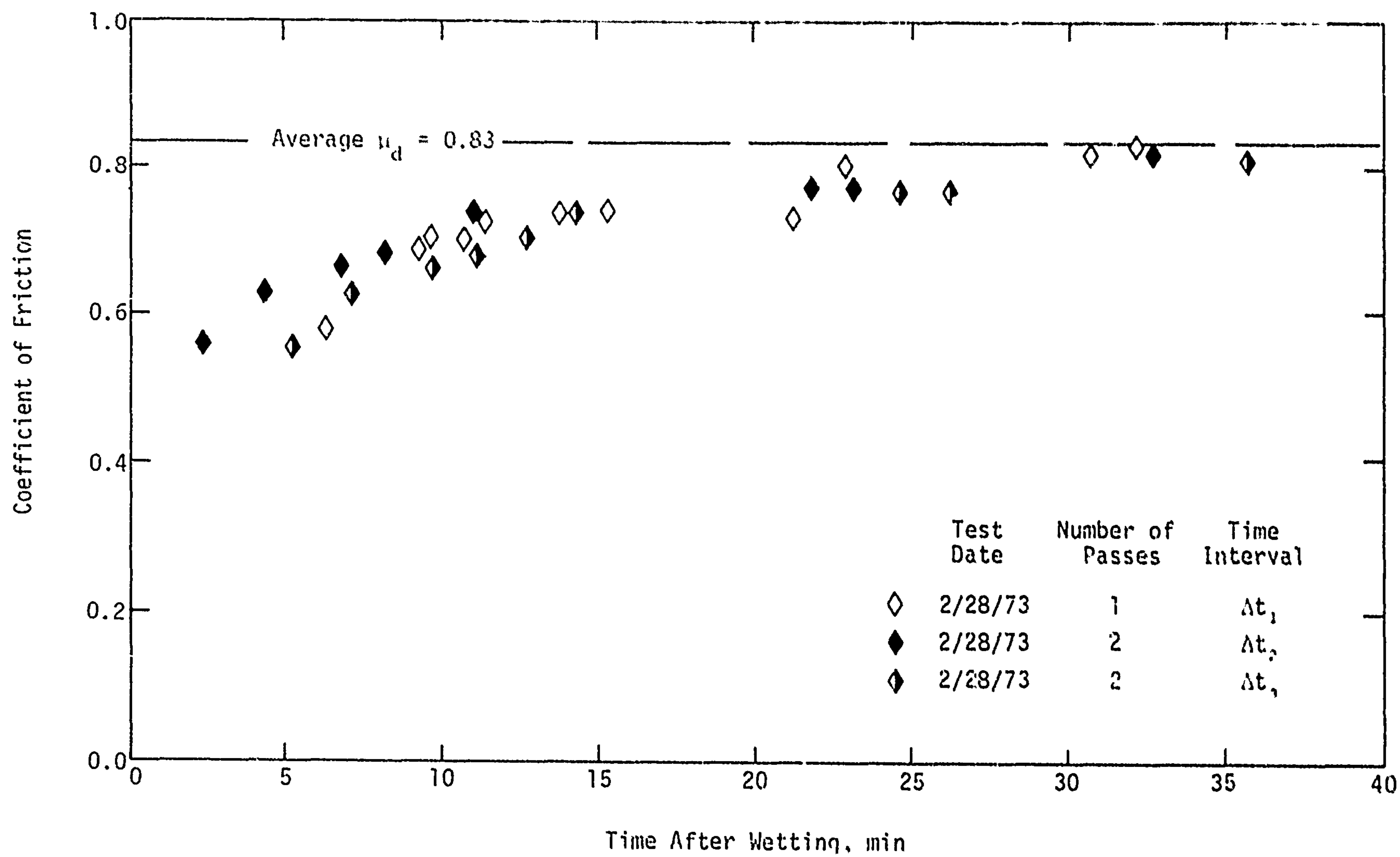

Figure 7. Coefficient of Friction versus Time After Wetting for 0.05-Inch Water Depth (Entire Test Area)

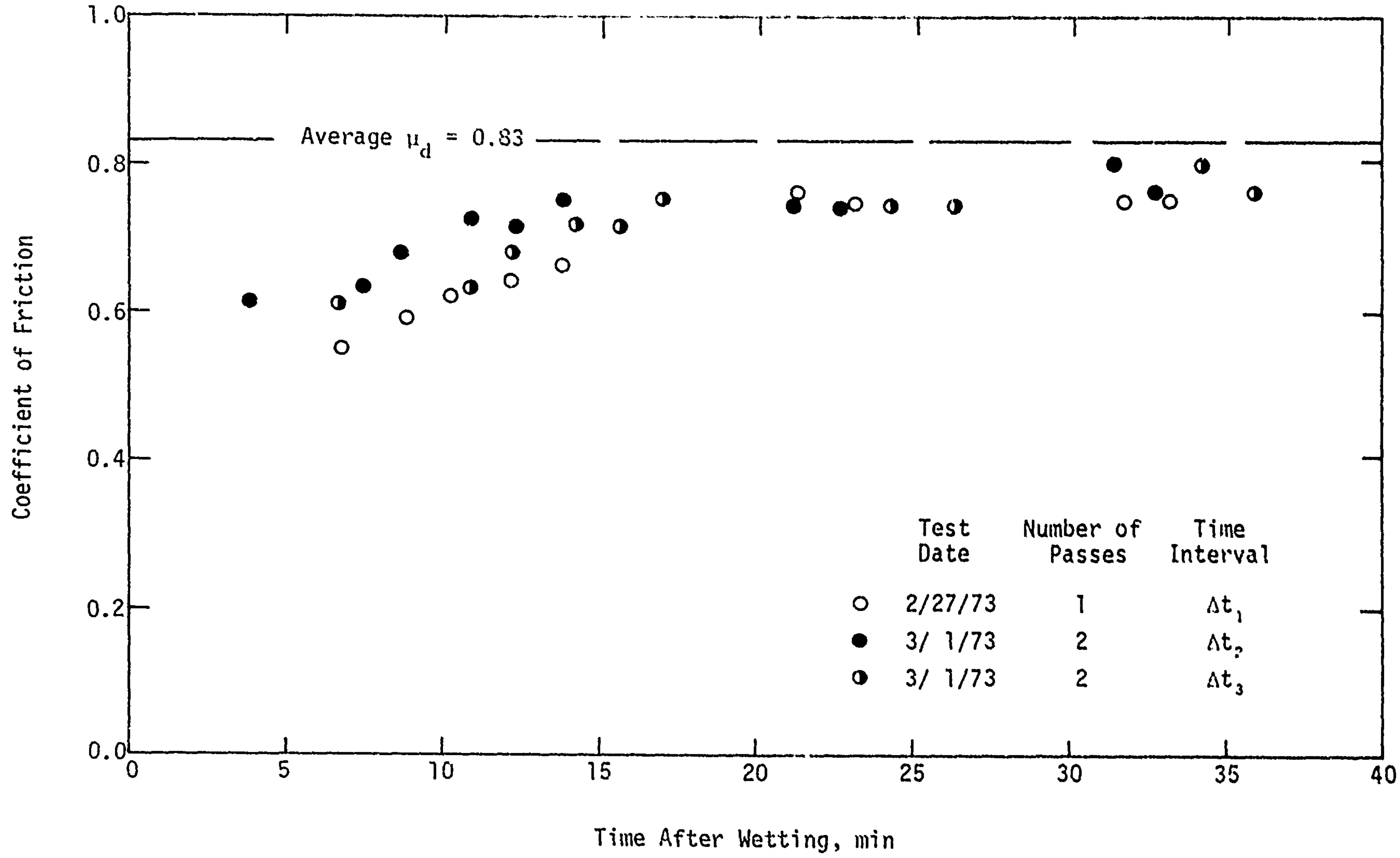

Figure 8. Coefficient of Friction versus Time After Wetting for 0.10-Inch Water Depth (Entire Test Area)

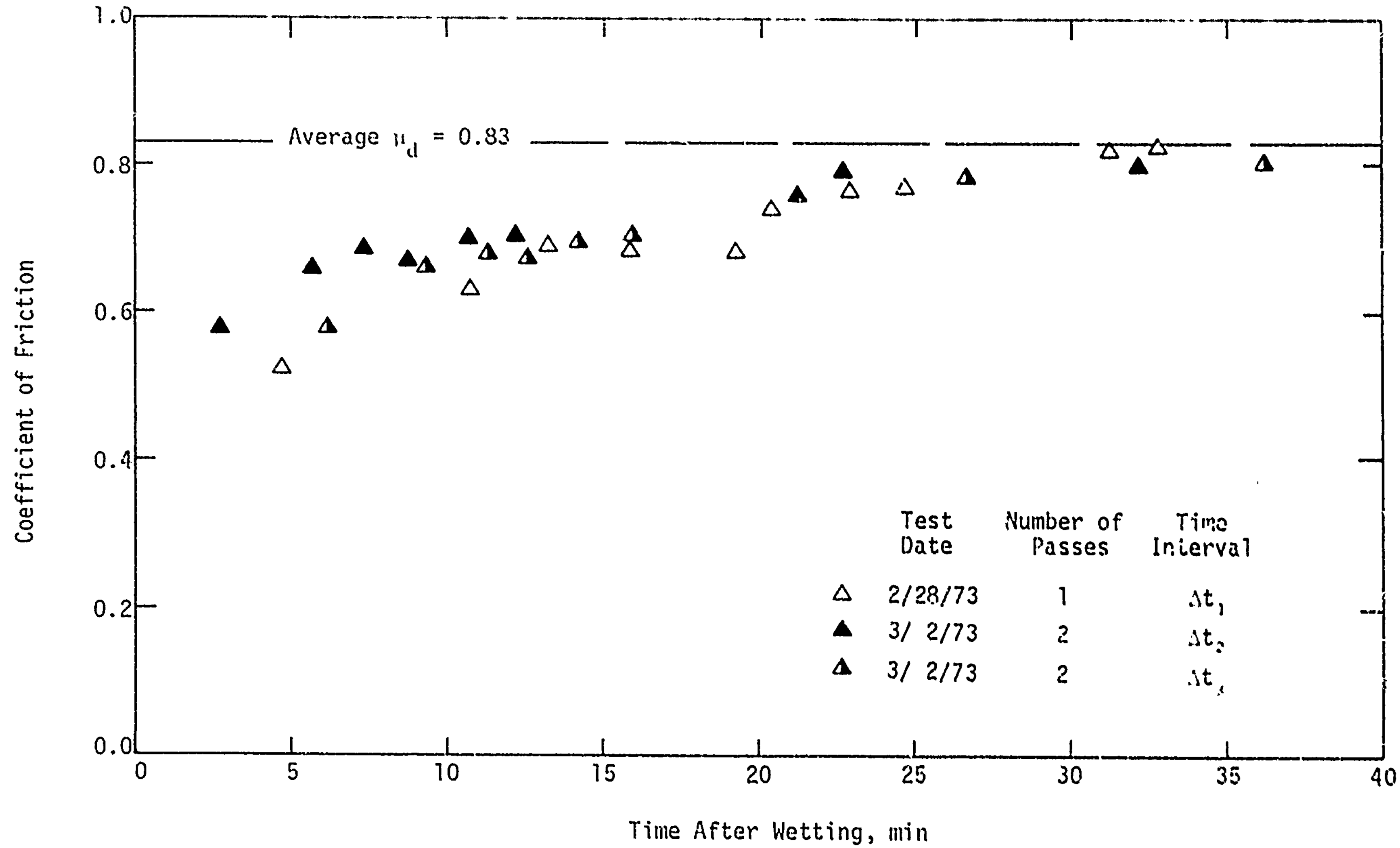

Figure 9. Coefficient of Friction versus Time After Wetting for 0.20-Inch Water Depth (Entire Test Area)

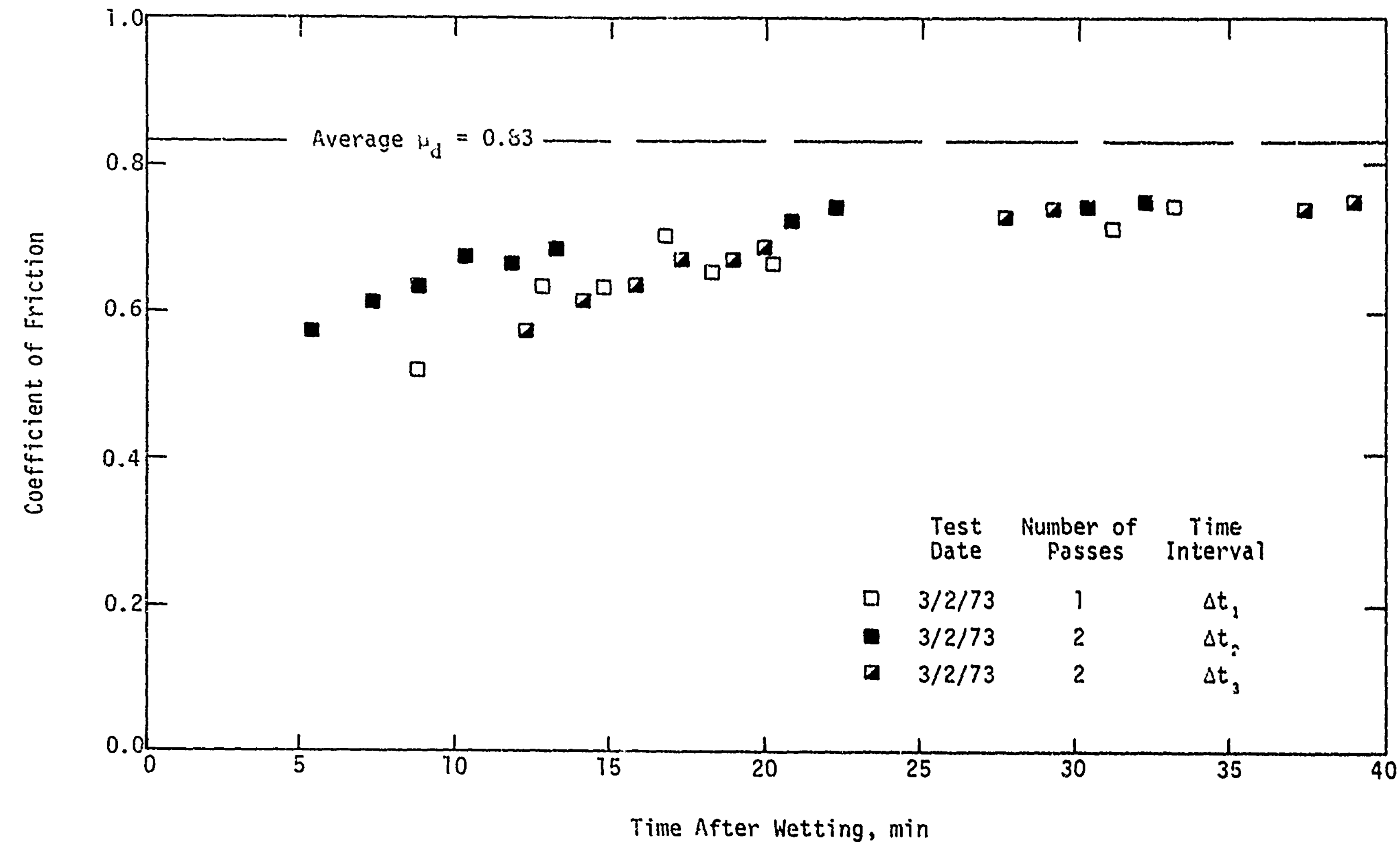

Figure 10. Coefficient of Friction versus Time After Wetting for 0.30-Inch Water Depth (Entire Test Area)

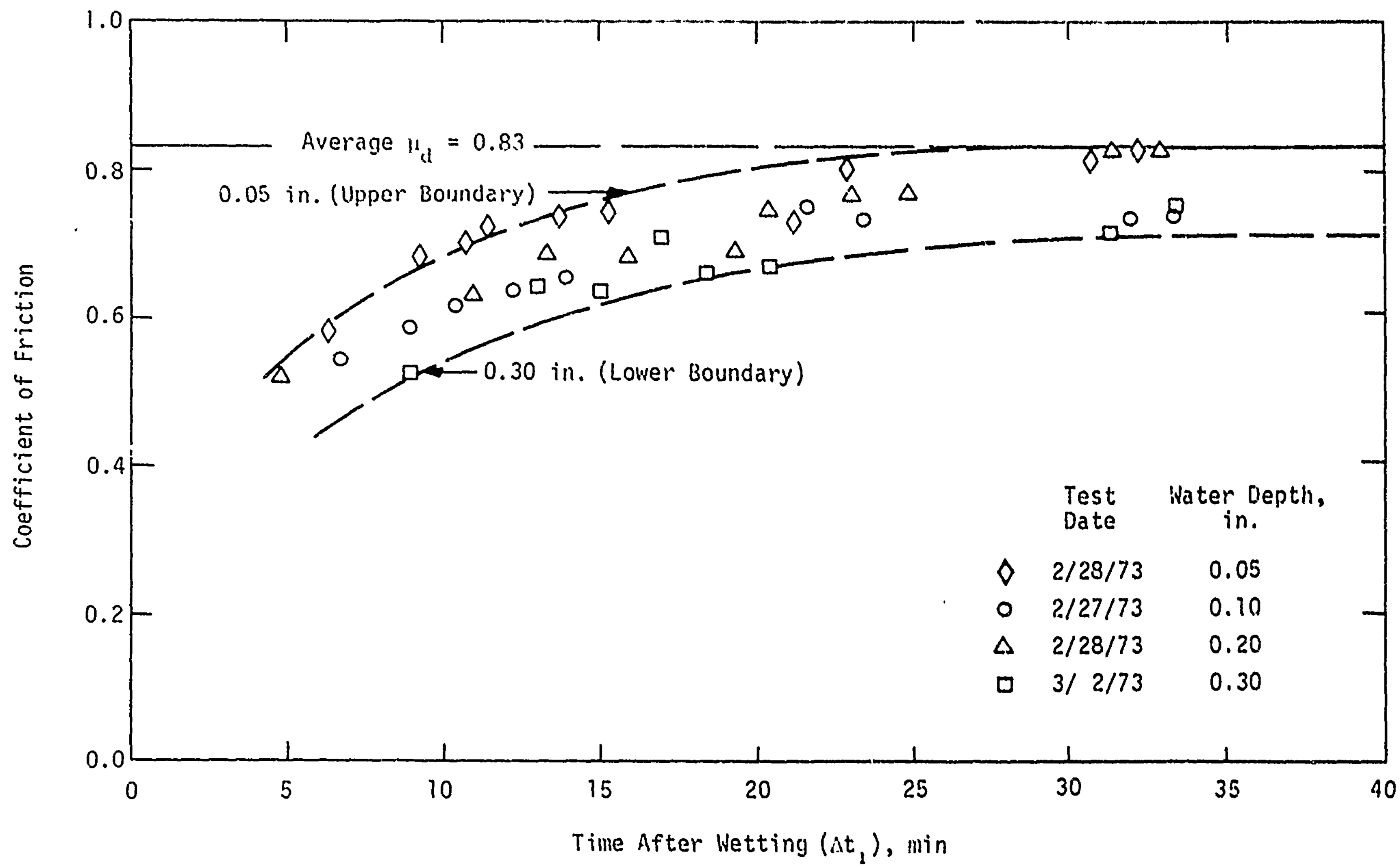

Figure 11. Coefficient of Friction versus Time After Wetting for Water Applied in One Pass (Entire Test Area)

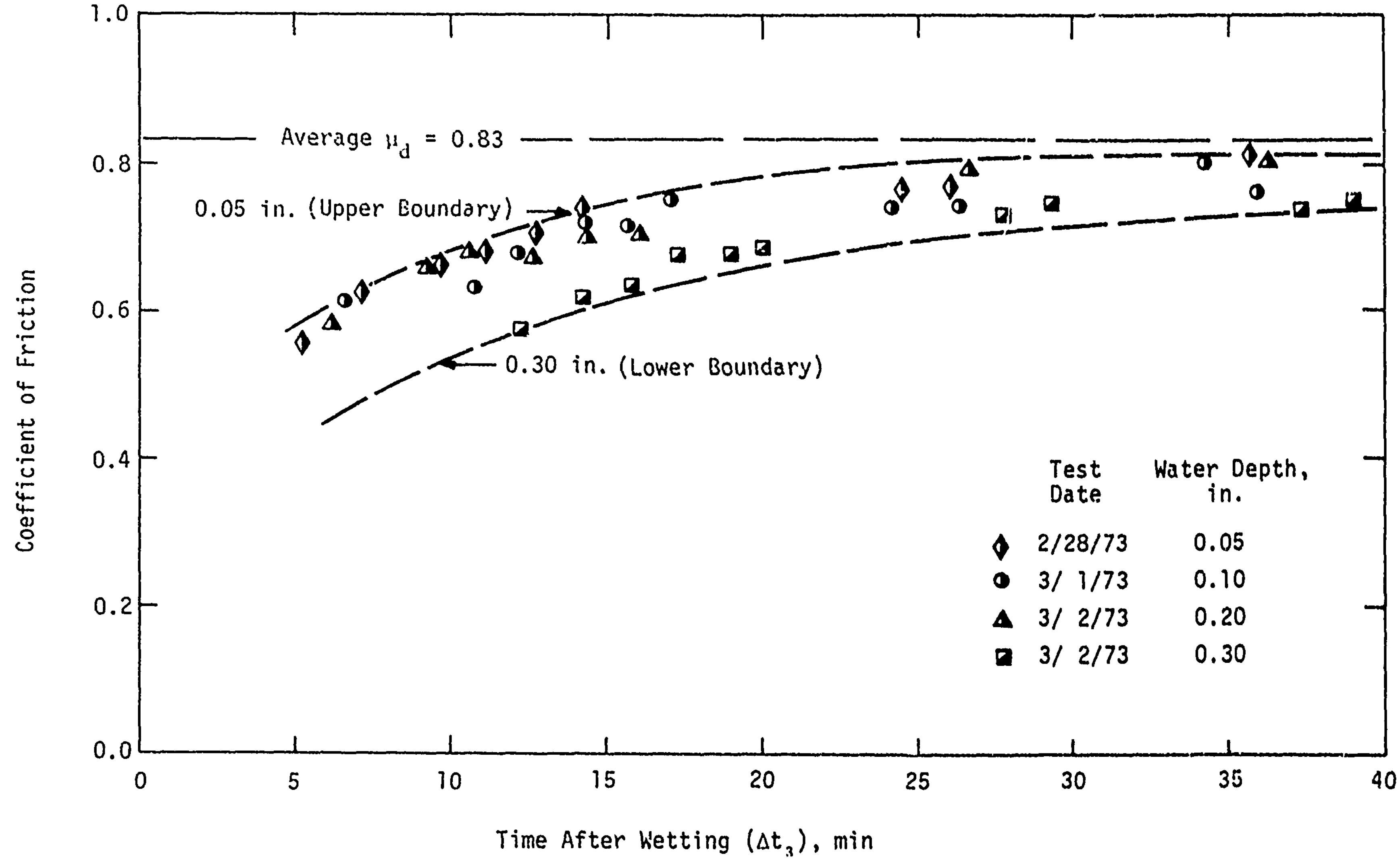

Figure 12. Coefficient of Friction versus Time After Wetting for Water Applied in Two Passes (Entire Test Area)

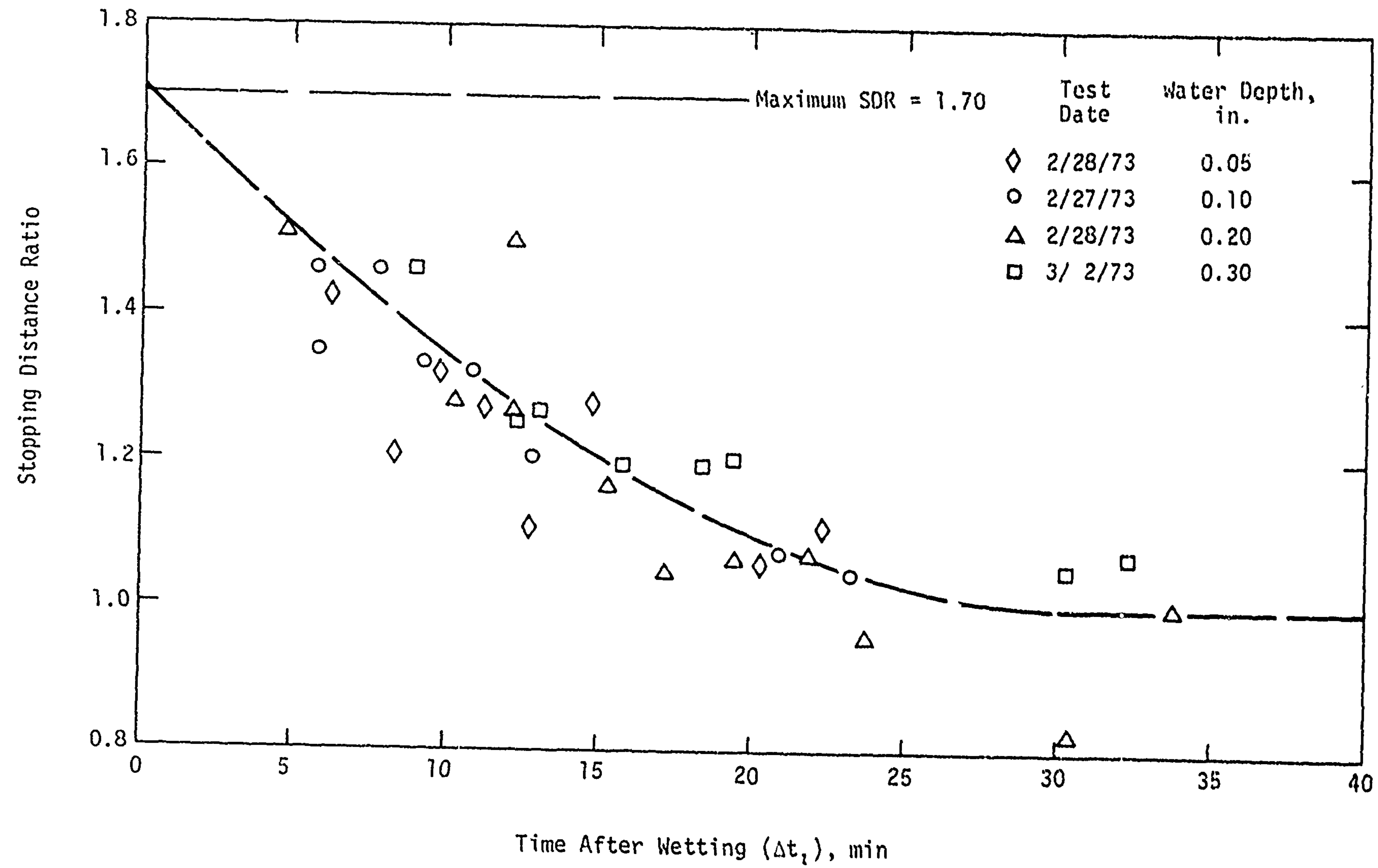

Figure 13. Stopping Distance Ratio versus Time After Wetting for Water Applied in One Pass (DBV Test Strip)

It should also be pointed out that the utilization of two water trucks for pavement wetting can greatly reduce the time interval of the initial data point on the friction recovery curves (figures 7 through 10).

Regarding the possibility of improving the standard AFWL test procedure by creating a more severe wetting condition, table IV summarizes the initial Mu-Meter values from appendix I, using Δt_1 and Δt_2 as the corresponding time intervals after wetting.

Table IV

INITIAL MU-METER VALUES

Applied Water, In	Δt_1 Min	Mu	Δt_2 Min	Mu
0.05	6.28	0.[illegible]	2.15	0.56
0.10	2.78	0.47	3.61	0.61
0.20	4.70	0.52	2.58	0.58
0.30	8.96	0.52	5.47	0.57

The limited data given in table IV would suggest that a single application of water may provide equal or even a slightly more severe wetting condition for testing. However, additional research should be conducted to establish this fact before any changes are made to the standard AFWL test procedure now in use.

2. STOPPING DISTANCE RATIO

The relationship between SDR and time after wetting for a single application of any given water depth, Δt_1, is shown in figure 13. The maximum SDR measured in this investigation was 1.70. An SDR of 1 indicates a full recovery to the dry condition after wetting. Examination of figure 13 reveals that there is no well-defined relationship to establish the influence of the time after wetting on the measured SDR. Furthermore, the data provide no discernible trend in regard to the influence of the initial amount of water on the measured SDR. In essence, the SDR measured by the DBV is not as sensitive a traction parameter to wetting conditions throughout the test area as the coefficient of friction measured by the Mu-Meter. The DBV provides an assessment of the traction characteristics of the pavement within the stopping distance of the vehicle only. The Mu-Meter furnishes a continuous traction record as well as an integrated average for the entire test area. Figure 14 displays the SDR versus time after wetting relationship for water applied in two passes, Δt_2. Although no specific trend is discernible to indicate the influence of the initial amount of water on the measured SDR, the average trend for a single application is very close to that for a double application. However, figures 13 and 14 show that the data dispersion at late times (after 35 to 40 min) is almost as persistent as that at early times. This is largely attributed to the fact that 35 to 40 min after wetting is not sufficient time for the pavement to revert to a dry condition, especially for the large initial water depths (0.20 and 0.30 in.).

3. STOPPING DISTANCE RATIO VERSUS COEFFICIENT OF FRICTION

The stopping distances measured by the DBV provide an opportunity of independently computing an average coefficient of friction for the pavement within the DBV test strip. This can be accomplished by assuming that the kinetic energy of the DBV is totally dissipated in producing work against the frictional resistance of the pavement during the skidding process. Since only two of the four wheels of the DBV are locked during the skidding process, the other two diagonally opposite wheels are left free rolling. The following expression can be written:

$$\frac{W}{2g} V^2 = \frac{W}{2} \mu_c \overline{SD} \qquad (1)$$

where

- W = weight of DBV
- V = initial velocity of DBV
- g = gravitational constant
- μ_c = calculated coefficient of friction
- $\overline{SD}$ = stopping distance

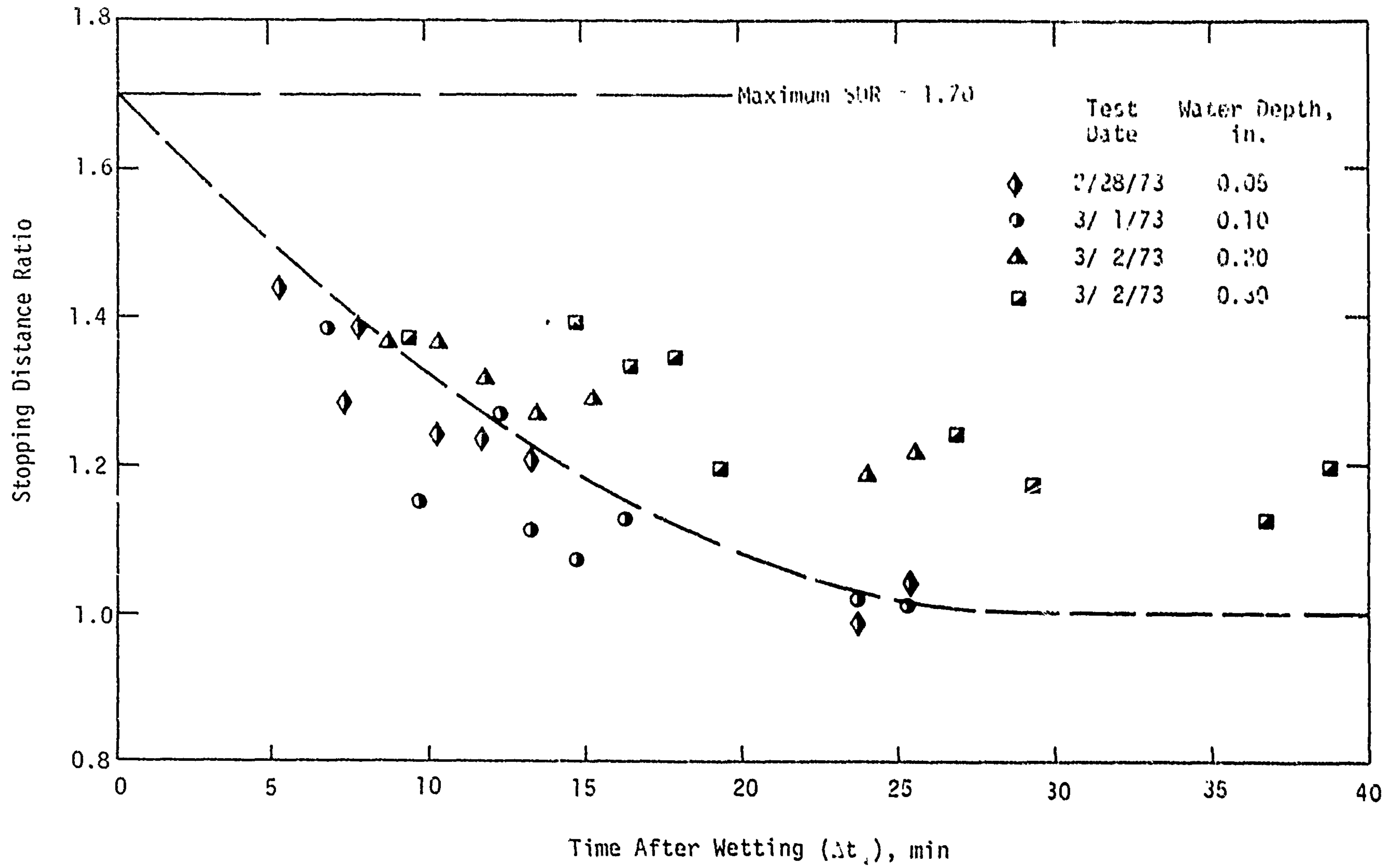

Figure 14. Stopping Distance Ratio versus Time After Wetting for Water Applied in Two Passes (DBV Test Strip)

Equation (1) when expressed in terms of the coefficient of friction and an initial constant velocity of 60 mph yields:

$$\mu_c = \frac{V^2}{g\overline{SD}} = \frac{240.5}{\overline{SD}} \tag{2}$$

Appendix I provides measured raw stopping distances (RSD) which correspond to the actual initial braking velocities and corrected stopping distances (CSD) which were obtained by multiplying the RSDs by the ratio of the velocities squared (i.e., $\overline{60}^2/V_m^2$), where V_m is the actual measured velocity at the instant the wheels lock. Such a correction is necessary because it is not always possible to brake at an initial velocity of 60 mph.

The coefficients of friction, μ_c, calculated from eq. (2) using the corresponding CSD values are also provided in appendix I.

Equation (2) when expressed in terms of stopping distance yields:

$$\overline{SD} = \frac{240.5}{\mu_c} \tag{3}$$

The left-hand side of eq. (3) was normalized by dividing both sides by the stopping distance on the dry pavement, $\overline{DSD}$, which was 336 ft for the DBV portion of the test area. Such a normalization yields:

$$\frac{\overline{SD}}{\overline{DSD}} = \frac{240.5}{336\mu_c}$$

or

$$SDR = \frac{0.716}{\mu_c} \tag{4}$$

Equation (4) represents the SDR in terms of a dry stopping distance of 336 ft which for this particular test area furnishes a theoretical relationship between SDR and the coefficient of friction for the pavement surface. The solid lines in figures 15 and 16 are graphical displays of eq. (4).

To assess the extent to which the coefficients of friction measured by the Mu-Meter fit the theoretical relationship of eq. (4), the data in appendix I labelled μ_m for the DBV test strip were superimposed on figures 15 and 16.

Although the theoretical relationship presented in figures 15 and 16 is the same, figure 15 reflects the measured coefficients of friction for a

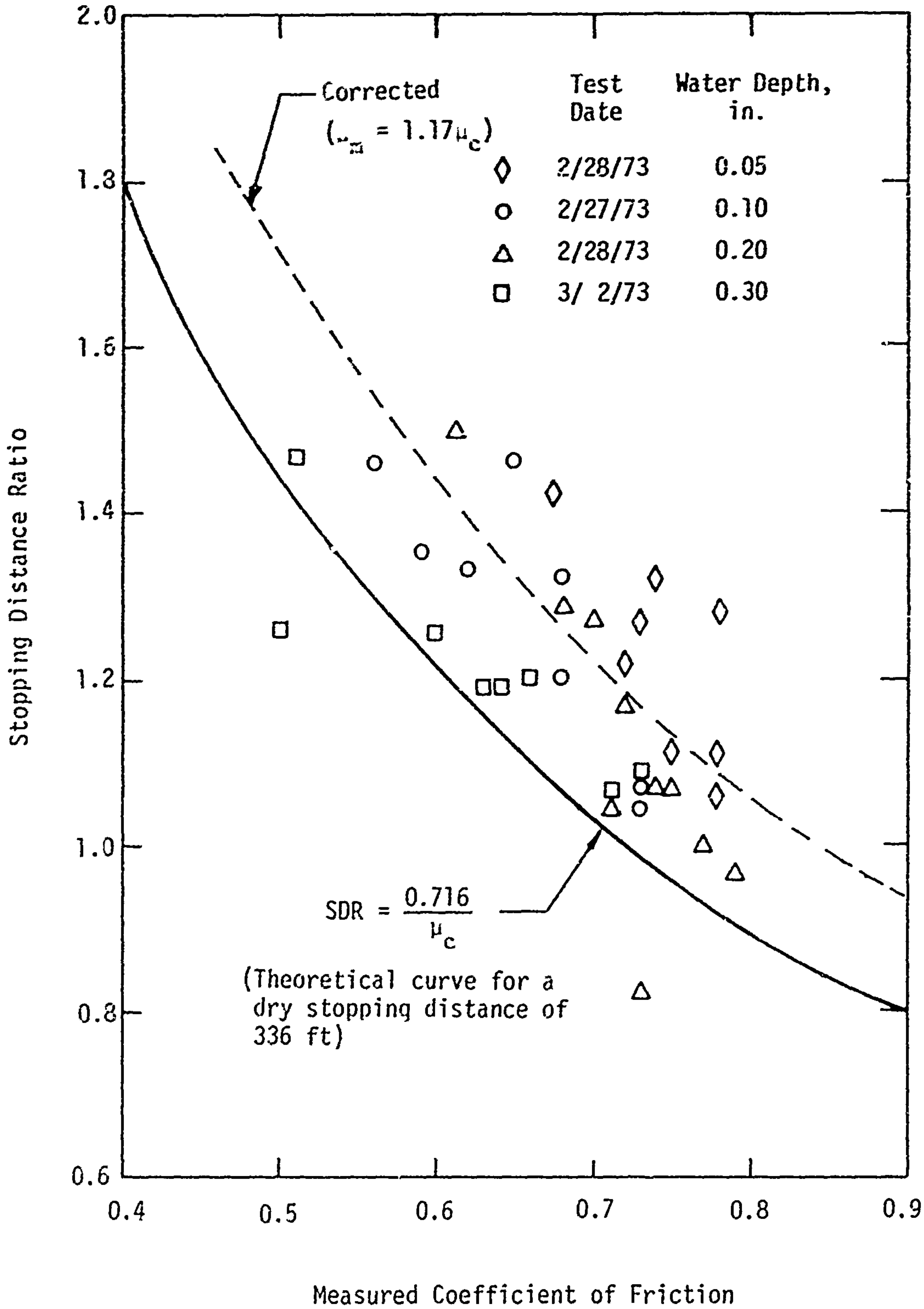

Figure 15. Stopping Distance Ratio versus Mu-Meter-Measured Coefficient of Friction for Water Applied in One Pass (DBV Test Strip)

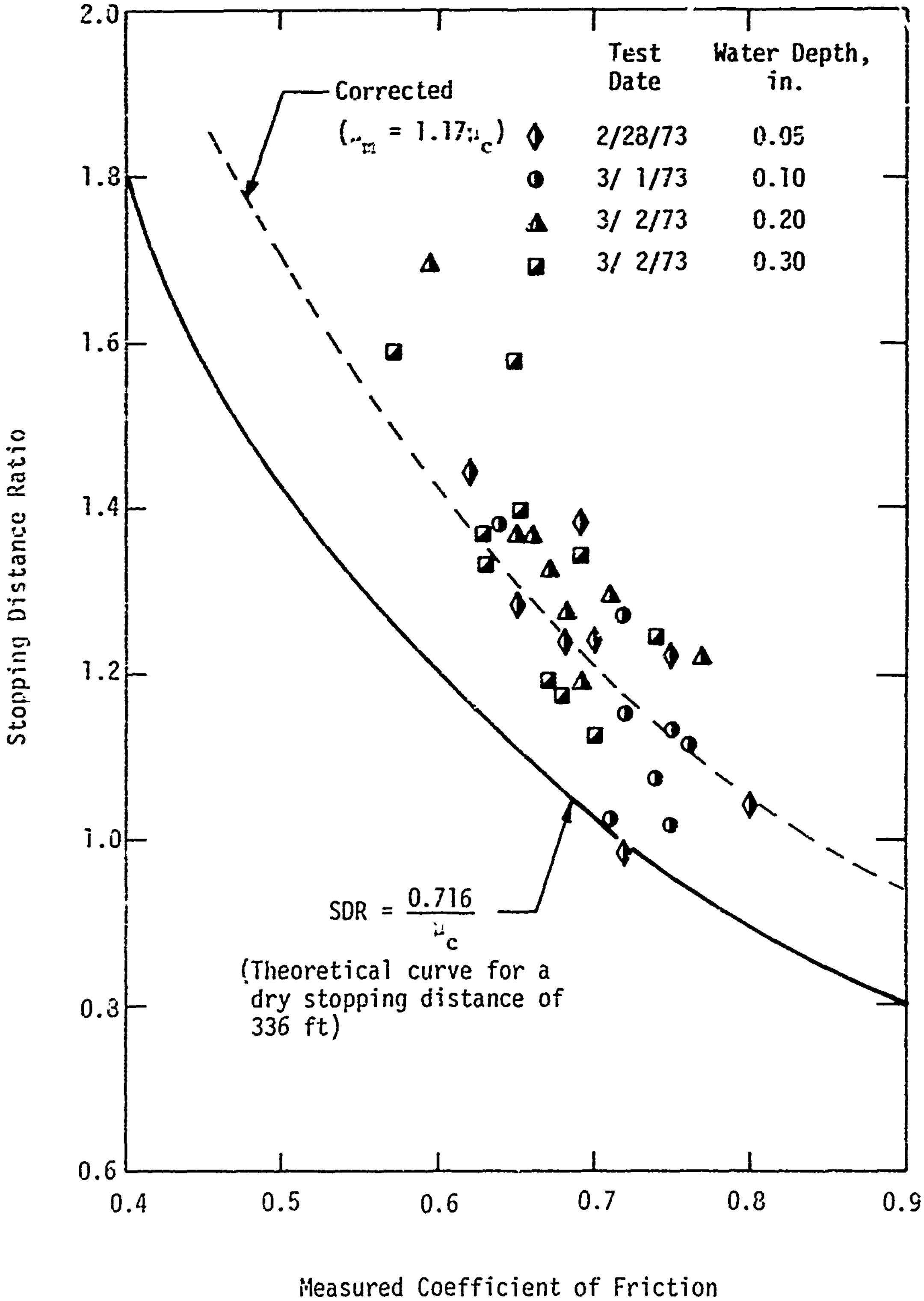

Figure 16. Stopping Distance Ratio versus Mu-Meter-Measured Coefficient of Friction for Water Applied in Two Passes (DBV Test Strip)

single-pass application of the four different water depths, and figure 16 reflects the influence on the measured coefficients of friction when the same four water depths were applied in two passes.

Figures 15 and 16 clearly indicate that for any SDR, the coefficients of friction measured by the Mu-Meter were substantially larger than those calculated by the theoretical relationship of eq. (4). Superposition of figures 15 and 16 also clearly reveals that the scatter in the measured coefficients of friction was approximately of the same order regardless of the method of water application (one or two passes).

The discrepancy between measured and calculated coefficients of friction can be more clearly illustrated by plotting the coefficients of friction measured by the Mu-Meter within the DBV test strip (labelled as arithmetic averages in appendix I) against the coefficients of friction calculated from the DBV data. (See DBV data in appendix I.) Such a plot is shown in figure 17. It shows that the data predominantly lie above a 45° line and clearly illustrates the fact that the Mu-Meter-measured coefficients of friction are invariably larger than the coefficients of friction calculated from the DBV data. The empirical relationship, $\mu_m = 1.17\mu_c$, provides a better fit between measured and calculated coefficients of friction. Such an empirical correction to the theoretical relationship given in figures 15 and 16 (dashed lines) provides better agreement between measured and calculated coefficients of friction. This empirical adjustment forces the theoretical curves in figures 15 and 16, for an SDR of 1, to pass through the measured dry coefficient of friction of 0.83 which also corresponds to the field measurement obtained on a dry pavement.

4. WATER DEPTH VERSUS TIME AFTER WETTING

Water depth is the most important parameter affecting the traction characteristics of airfield pavements. Consequently, it should be the most significant parameter against which either coefficients of friction or SDRs are correlated. Since water on the pavement surface dissipates with time after wetting, the existence of correlations between water depth and the coefficient of friction or between water depth and SDR strongly depends on a well-defined relationship of measured water depth as a function of time after wetting. Figure 18 displays water depth versus time after wetting for various amounts of water applied in one and two passes (data extracted from appendix II). Since the data are not arrayed in any consistent pattern, a meaningful interpretation

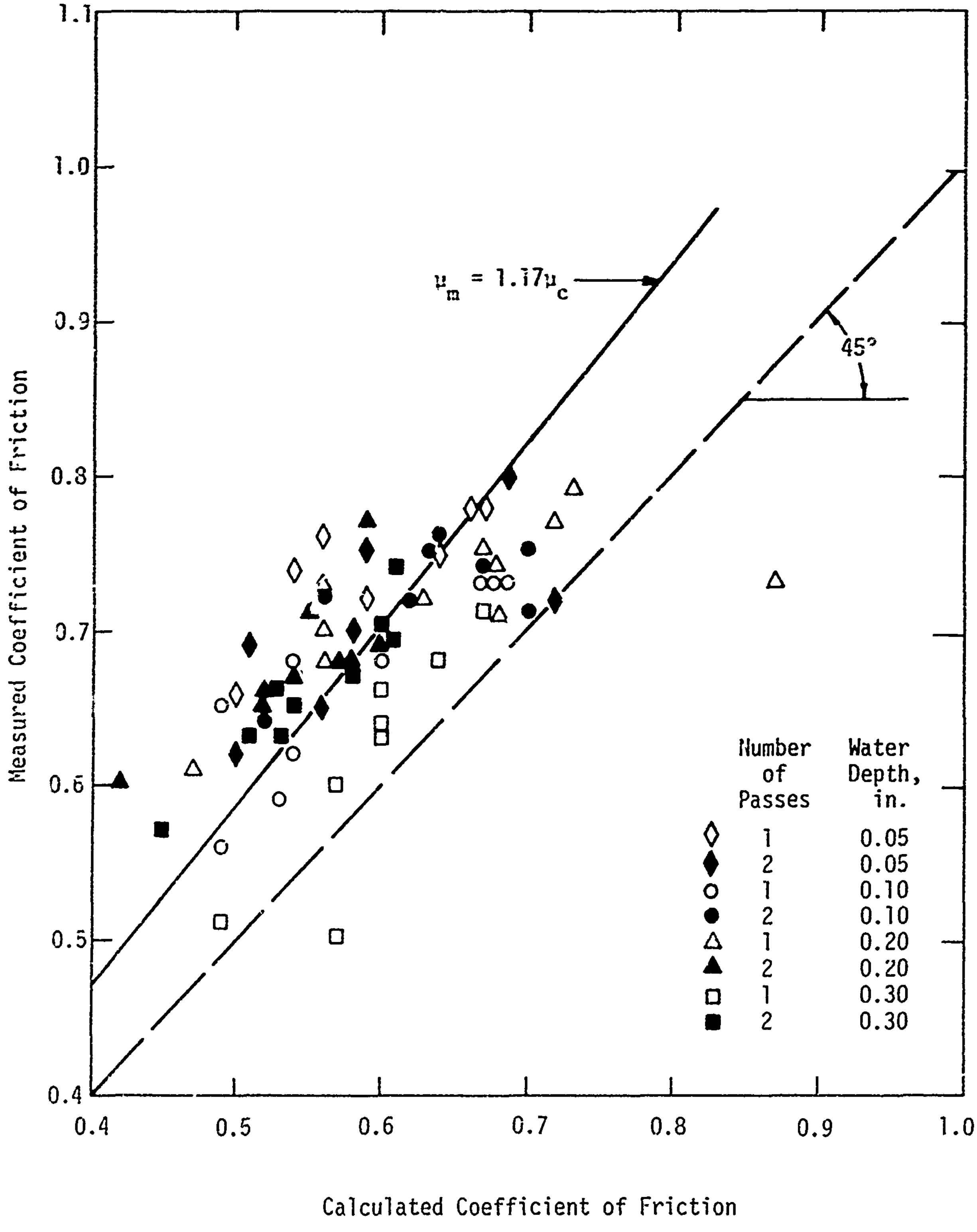

Figure 17. Comparison of Coefficients of Friction Measured by Mu-Meter and Calculated from DBV Data (DBV Test Strip)

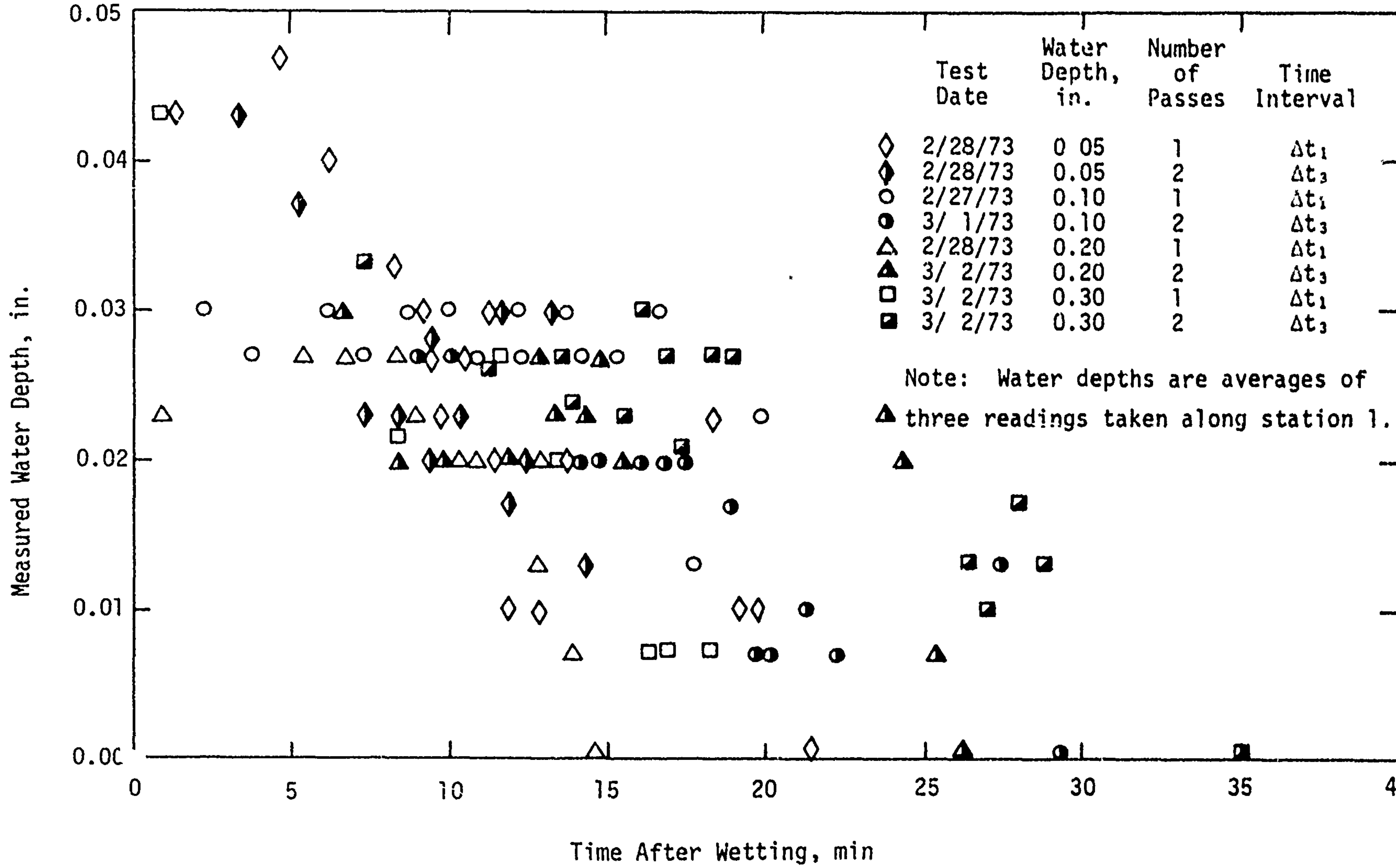

Figure 18. Water Depth versus Time After Wetting for DBV Test Strip (Station 1)

of the variables affecting the measured water depth cannot be made. (The water depths given in this figure represent the average of three readings taken along station 1.) Although water-depth measurements are very important in assessing the hydroplaning and traction characteristics of airfield pavements, the method used to measure the water depth is not precise enough to delineate water depths with the necessary accuracy and reliability. The NASA water-film depth gage used in this investigation is a simple device the reading of which requires a visual interpretation of the amount of light reflected through the plastic rods that are in contact with the water surface. These readings are greatly influenced by the positioning of the gage on the pavement surface and by the extent to which the instrument can be identically repositioned for subsequent measurements. The readings are furthermore affected by human error and the positioning of the three supporting prongs with respect to irregularities in the pavement surface. It is, therefore, not surprising that the data presented in figure 18 display no specific trends to provide a relationship between water depth and time after wetting for the various water depths and methods of application. In this connection, it is also emphasized that in contrast to the coefficients of friction measured by the Mu-Meter which represent average values for the entire test area, the water-depth measurements represent individual values at specific locations and, therefore, correlations are hard to establish unless the measured coefficients of friction pertain to specific locations or the water-depth measurements represent an integrated average over the entire run on the test area.

5. MU-METER-MEASURED AND DBV-CALCULATED COEFFICIENTS OF FRICTION VERSUS TIME AFTER WETTING

Figure 19 shows both the coefficients of friction measured by the Mu-Meter and those calculated from the DBV data as a function of time after wetting for the DBV test strip. This comparison pertains to the 0.05-in. water depth applied in one pass. Although arithmetic averages for the coefficients of friction measured by the Mu-Meter within the DBV test strip are available from blip marks on the Mu-Meter tape, the corresponding times after wetting were calculated from the traversing speed of the Mu-Meter. The distance from the middle of the entire test area to the middle of the DBV test strip is about 500 ft (fig. 1). At a speed of 40 mph, depending on the direction of travel, the Mu-Meter crossed the midpoint of the DBV test strip at $\Delta t_1 \pm 0.14$ min.

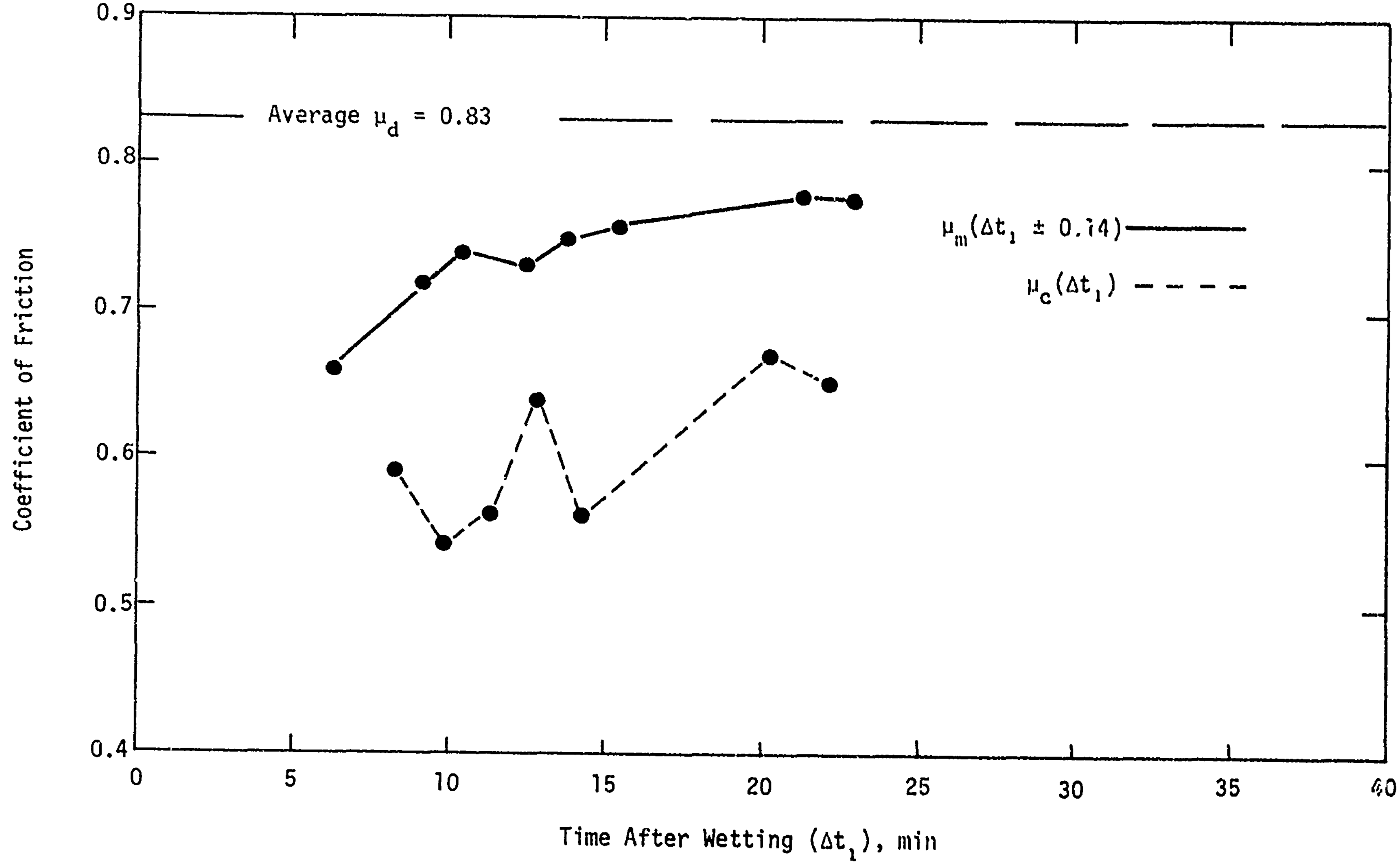

Figure 19. Comparison of Coefficients of Friction Measured by Mu-Meter and Calculated from DBV Data versus Time After Wetting for 0.05-Inch Water Depth Applied in One Pass (DBV Test Strip)

Figure 20 presents the data for the 0.20-inch water depth applied in two passes. The corrected time after wetting for the Mu-Meter data in this case was $\Delta t_3 \pm$ 0.14 minutes. From figures 19 and 20 it is evident that the coefficients of friction measured by the Mu-Meter were not seriously influenced by directional effects. Some indications of directional effects may be shown by the wider scatter of the DBV calculated Mu-Meter values. The DBV has shown from previous testing to have a somewhat wider data scatter than the Mu-Meter, and this fact may also have an influence on the calculated friction valves.

6. REPEATABILITY OF TRACTION DATA

The traction and water-depth test data presented in appendix I and II, respectively, were gathered between February 27 and March 2, 1973. Since repeatability of pavement traction data was of interest, tests involving the 0.20-inch water depth applied in one and two passes were repeated on September 27, 1973. A DBV was not available at this time; therefore, the data were limited to Mu-Meter measurements of the entire test area (appendix III) and water-depth measurements at station 1 (appendix IV).

Figure 21 shows average coefficients of friction for the entire test area versus time after wetting. The time after wetting was interpreted as Δt_1 for a single application of 0.20 inch of water, and both as Δt_2 and Δt_3 when the 0.20 inch of water was applied in two passes.

Comparison of figure 21 and figure 9 reveals that in general the data in figure 21 exhibit a slower rate of friction recovery. The variation of the data is less prnounced at early times after wetting (0 to 15 minutes), but somewhat more prnounced beyond 15 minutes. The data variation, although not significant for the time interval after 15 minutes may be attributed to the different environmental conditions affecting the evaporation and drainage; however, the critical time period for pavement traction evaluation is 3 to 15 minutes after wetting.
cates that the data of figure 21 fall within upper and lower boundaries of figures 11 and 12, which ascertains the fair degree of repeatability of the test data.

Figure 22 shows the water-depth data for station 1 as a function of time after wetting, interpreted both as Δt_1 and Δt_3. These data show a more consistent trend than the water-depth data in figure 18. In view of the inherent drawbacks and the lack of sensitivity of the water-film depth gage, no attempt

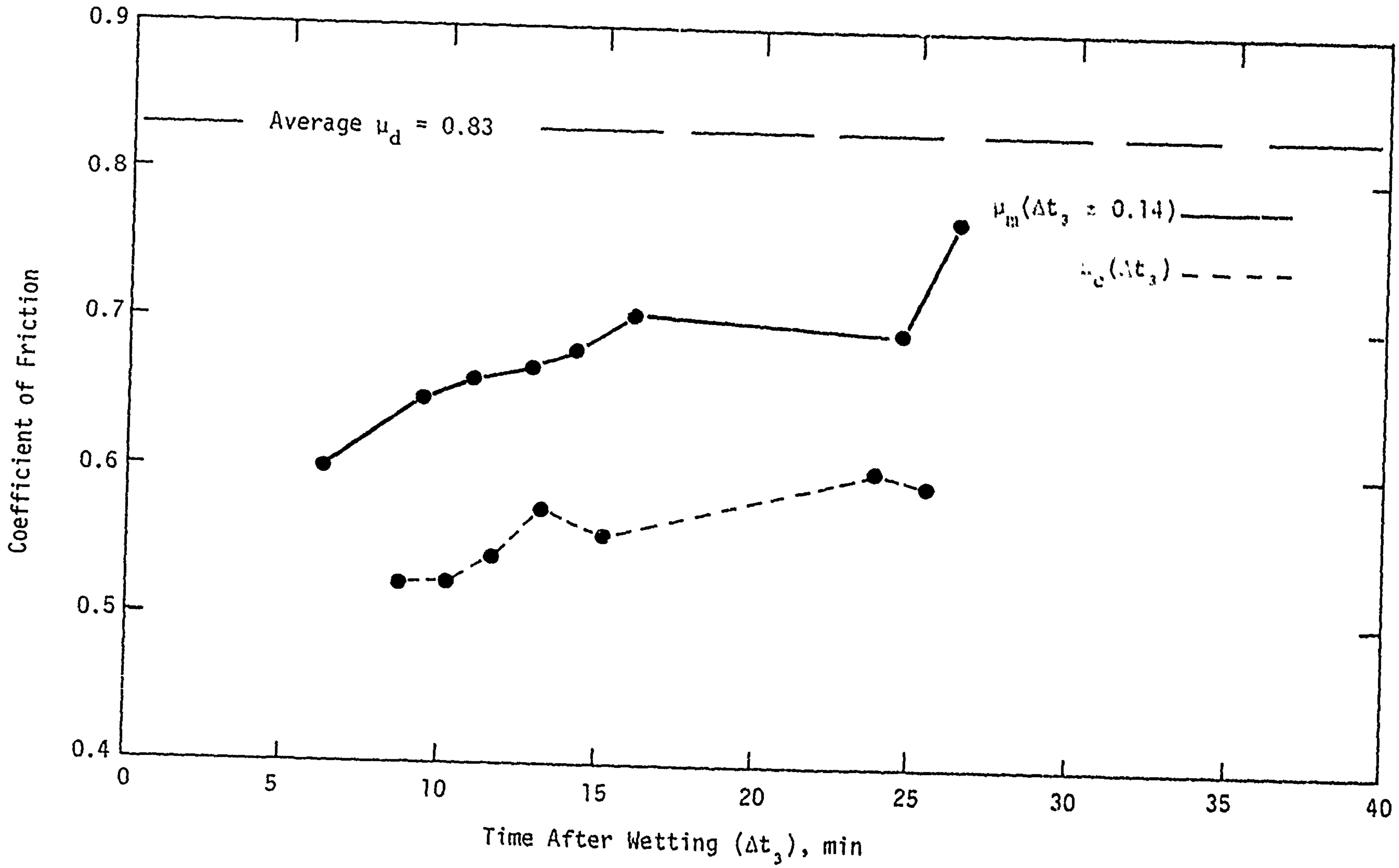

Figure 20. Comparison of Coefficients of Friction Measured by Mu-Meter and Calculated from DBV Data versus Time After Wetting for 0.20-Inch Water Depth Applied in Two Passes (DBV Test Strip)

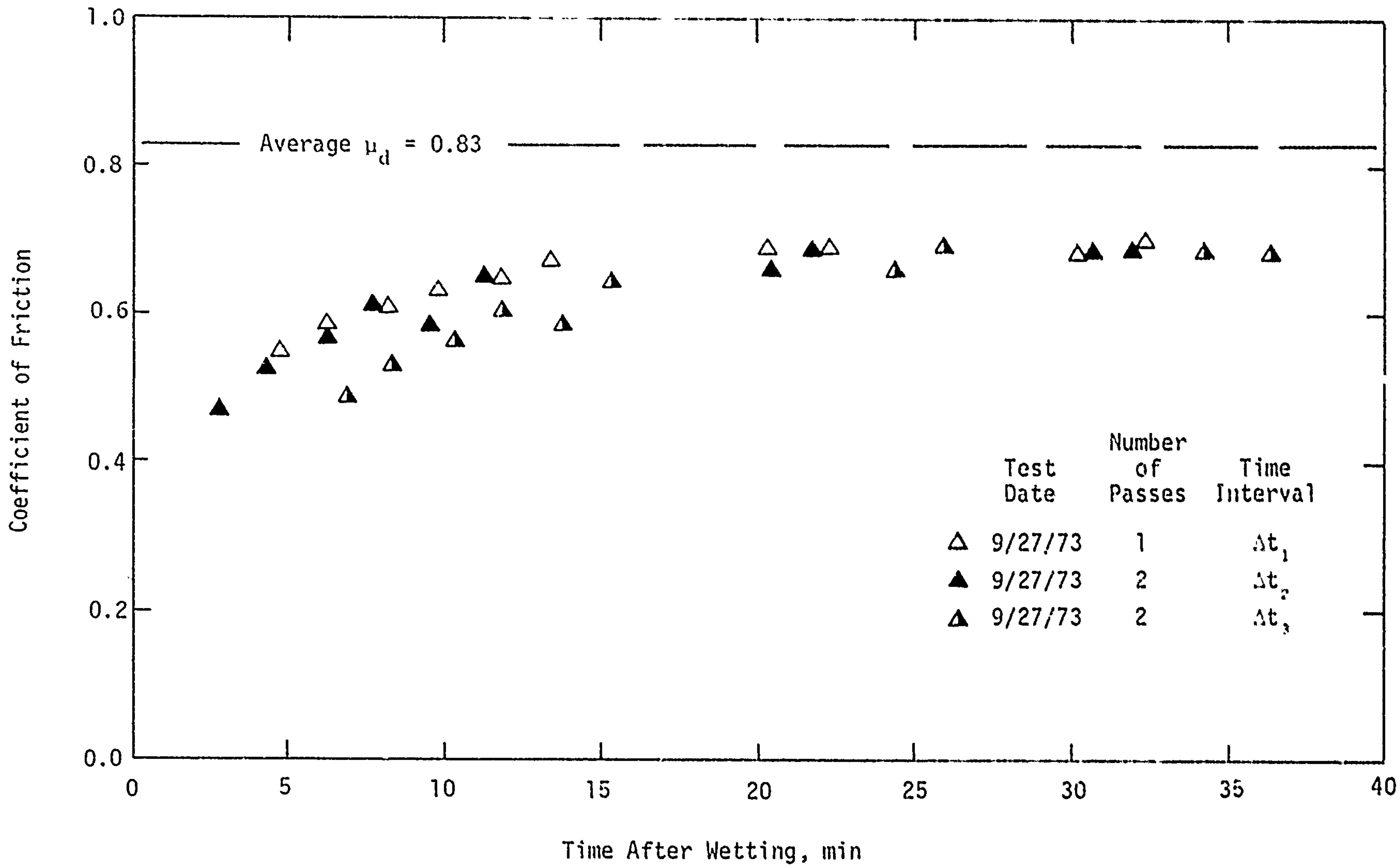

Figure 21. Coefficient of Friction versus Time After Wetting for 0.20-Inch Water Depth (Repeatability Data for Entire Test Area)

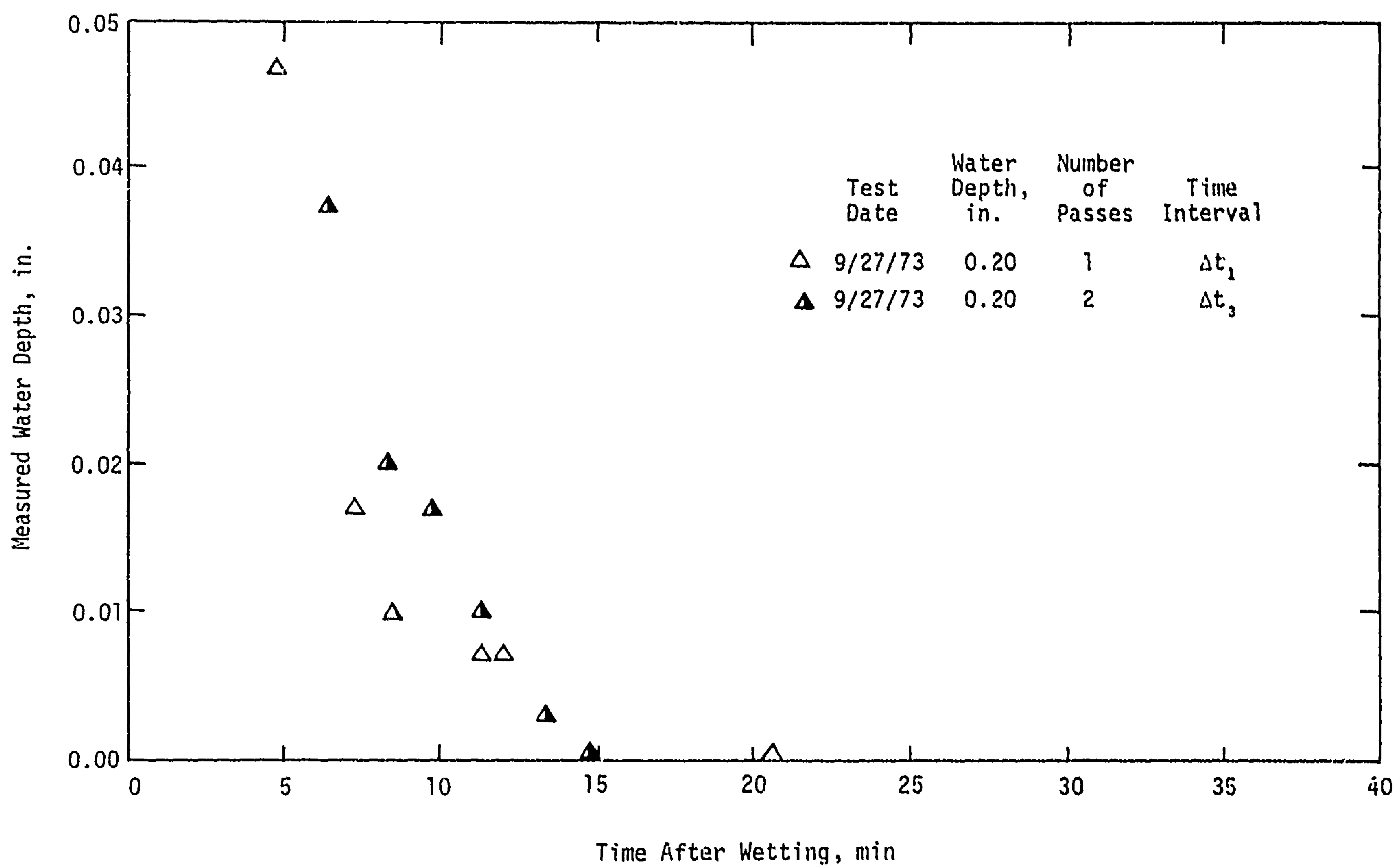

Figure 22. Water Depth versus Time After Wetting for DBV Test Strip (Repeatability Data for Station 1)

was made to explain the improved consistency observed in the second set of data (September 27, 1973).

SECTION VII
CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS

In regard to Mu-Meter measurements, larger amounts of water create more adverse traction conditions on the pavement surface (fig. 11). Comparison of figures 11 and 12 indicates that this is true regardless of whether the given amount of water is applied in one or two passes. For extreme variations of water depth, the data provide a fairly good delineation of the effect of water depth on the recovery of the coefficient of friction. (Compare 0.05 and 0.30 inch of water in both figures 11 and 12.) However, for the intermediate water depths (i.e., 0.10 and 0.20 inch) the trend is obscure. The physical limitations of placing 0.3 inch of water on the test section, the time involved in such an operation, and the earliest time after wetting for data collection do not warrant a change in the standard test procedures at this time. However, consideration of discharging 0.2 inch of water in a single pass might be considered in future test programs. This would simplify the test procedure and minimize the time involved to conduct the test. As noted by comparing the single pass 0.2 inch and double pass applications, there is very little difference in time after wetting for the first data point. Given an adequate water truck capability (high discharge rate), the time after wetting for the first data point could be less than 3 minutes.

In regard to DBV measurements, figures 13 and 14 indicate that only a general trend between SDR and time after wetting can be established. The data for both one- and two-pass applications of water are so thoroughly dispersed that no orderly array of the effect of water depth is discernible. This simply reaffirms the fact that the DBV is not as responsive as the Mu-Meter to variations in initial water depth or rapidly changing water depths.

The coefficients of friction measured by the Mu-Meter within the DBV test strip do not seem to substantiate the theoretical relationship between SDR and coefficients of friction calculated from DBV data (figs. 15 and 16). Invariably, for a given SDR, the coefficients of friction measured by the Mu-Meter were larger than those computed from DBV data. The same phenomenon is explicitly illustrated by the data in figure 17 where the measured coefficients of friction are plotted against those calculated from DBV data. These data consistently lie above a 45-degree line; whereby the empirical relationship μ_m = 1.17 provides a better correspondence to the experimental data. When such a correction is applied to the theoretical relationship given by eq. (4), better agreement between Mu-Meter-measured and DBV-calculated coefficients of friction results (figs. 15 and 16). Neither the influence of water depth nor the influence of the number of passes is discernible from the experimental data given in figures 15 and 16.

The equipment for water-depth measurements is not sensitive enough to provide an accurate delineation of the influence of the pavement drainage characteristics on the dissipation of water as a function of time after wetting. Although water depth is the most important parameter in assessing the hydroplaning and traction characteristics of airfield pavements, the data in figure 18 indicate no evidence of any specific trends with respect to either total amount of applied water or the method of application.

A comparison of the data in figure 9 (obtained with the Mu-Meter during the test period of February 27 to March 2, 1973) and similar data (obtained on September 27, 1973) indicates a fair degree of reproducibility in the rate of recovery of the coefficient of friction.

2. RECOMMENDATIONS

Water depth is the most important parameter in assessing the hydroplaning and traction characteristics of an airfield pavement. However, the equipment used for water-depth measurements is neither sensitive nor accurate enough to delineate the variations in water depth as a function of time after wetting. Consequently, future research should be aimed toward developing a method of rapidly measuring water-depth on a runway surface. Such a system could be utilized most advantageously to continuously monitor the water present on the runway surface during flight operations. A system that could provide an integrated average water depth between any two points on the pavement surface is highly desirable. Therefore, the possibility of utilizing electrical contact probes, sonic devices, or ultrasonic techniques should be thoroughly investigated. Development of such an advanced system would increase the possibility of direct correlation of water depth and aircraft landing performance.

APPENDIX I

WET-RUN TRACTION DATA

(February 27 through March 2, 1973)

WET-RUN TRACTION DATA FOR 0.05-INCH WATER DEPTH, ONE PASS

Date: 2/28/73
Test Area Identification: Taxiway 2
Test Section Bearing: 08/26
Wind Direction: 08°
Wind Velocity: 2 to 6 knots
Relative Humidity: 50%
Air Temperature: 46°F

1st Pass
Time In: 09:05:00
Time Out: 09:07:36
2nd Pass
Time In:
Time Out:
Zero Reference Time: t_{o_1} = 09:06:18

Weather: Fair & Clear
Asphalt Temperature: 50 to 76°F
Average Dry Coefficient of Friction
Entire Test Area: 0.82
DBV Strip: 0.78
Dry Stopping Distance: 336 ft

Test Vehicle	Test Run Identification	Clock Time (t_{f_1}), hr:min:sec	Elapsed Time (Δt_1), min	Mu-Meter Coefficient of Friction (μ_m)						DBV Data			
				Entire Test Area			DBV Test Strip						
				Min.	Max.	Integ. Avg.	Min.	Max.	Arith. Avg.	RSD, ft	CSD, ft	SDR	μ_c
DBV	1W1.05E									462	478	1.42	0.50
Mu-Meter	1W1.05E	09:12:35	6.28	0.40	0.70	0.58	0.50	0.72	0.66				
DBV	2W1.05W	09:14:28	8.17							395	408	1.21	0.59
Mu-Meter	3W1.05W	09:15:25	9.12	0.58	0.76	0.69	0.67	0.76	0.72				
DBV	3W1.05E	09:16:06	9.80							445	445	1.32	0.54
Mu-Meter	3W1.05E	09:16:56	10.63	0.56	0.67	0.70	0.70	0.78	0.74				
DBV	4W1.05W	09:17:40	11.37							442	427	1.27	0.56
Mu-Meter	4W1.05W	09:18:27	12.15	0.59	0.79	0.73	0.67	0.79	0.73				
DBV	5W1.05E	09:19:08	12.83							401	375	1.11	0.64
Mu-Meter	5W1.05E	09:19:59	13.68	0.64	0.82	0.74	0.70	0.80	0.75				
DBV	6W1.05W	09:20:44	14.63							430	430	1.28	0.56
Mu-Meter	6W1.05W	09:21:30	15.20	0.60	0.80	0.74	0.72	0.80	0.76				
DBV	7W1.05E	09:26:43	20.32							381	357	1.06	0.67
Mu-Meter	7W1.05E	09:27:35	21.28	0.57	0.82	0.73	0.74	0.80	0.78				
DBV	8W1.05W	09:28:21	22.05							385	372	1.11	0.65
Mu-Meter	8W1.05W	09:29:07	22.82	0.70	0.82	0.80	0.74	0.81	0.78				
Mu-Meter	9W1.05E	09:36:50	30.53	0.70	0.82	0.82							
Mu-Meter	10W1.05W	09:38:20	32.03	0.71	0.83	0.82							

WET-RUN TRACTION DATA FOR 0.10-INCH WATER DEPTH, ONE PASS

Date: 2/27/73
Test Area Identification: Taxiway 2
Test Section Bearing: 08/26
Wind Direction: 22°
Wind Velocity: 7 knots
Relative Humidity: 22%
Air Temperature: 61°F

1st Pass
Time In: 14:38:44
Time Out: 14:43:14
2nd Pass
Time In:
Time Out:
Zero Reference Time: t_{o_1} = 14:40:59

Weather: Partly Cloudy
Asphalt Temperature: 48 to 63°F
Average Dry Coefficient of Friction
Entire Test Area: 0.83
DBV Strip: 0.81
Dry Stopping Distance: 336 ft

Test Vehicle	Test Run Identification	Clock Time (t_{f_1}), hr:min:sec	Elapsed Time (Δt_1), min	Mu-Meter Coefficient of Friction (μ_m)						DBV Data			
				Entire Test Area			DBV Test Strip						
				Min.	Max.	Integ. Avg.	Min.	Max.	Arith. Avg.	RSD, ft	CSD, ft	SDR	μ_c
DBV	1W1.1E									428	491	1.46	0.49
Mu-Meter	1W1.1E	14:43:46	2.78	0.14	0.68	0.47	0.45	0.68	0.56				
DBV	2W1.1W	14:46:52	5.89							471	455	1.35	0.53
Mu-Meter	2W1.1W	14:47:47	6.80	0.22	0.69	0.55	0.49	0.69	0.59				
DBV	3W1.1E	14:48:31	7.54							509	492	1.46	0.49
Mu-Meter	3W1.1E	14:49:45	8.77	0.20	0.74	0.59	0.55	0.74	0.65				
DBV	4W1.1W	14:50:34	9.59							448	448	1.33	0.54
Mu-Meter	4W1.1W	14:51:23	10.40	0.30	0.74	0.62	0.50	0.74	0.62				
DBV	5W1.1E	14:52:05	11.10							491	445	1.32	0.54
Mu-Meter	5W1.1E	14:53:10	12.19	0.31	0.76	0.64	0.60	0.76	0.68				
DBV	6W1.1W	14:53:58	12.99							443	402	1.20	0.60
Mu-Meter	6W1.1W	14:54:43	13.74	0.44	0.77	0.66	0.58	0.77	0.68				
DBV	7W1.1E	15:01:54	20.92							373	361	1.07	0.67
Mu-Meter	7W1.1E	15:02:25	21.44	0.34	0.79	0.76	0.68	0.77	0.73				
DBV	8W1.1W	15:04:18	23.32							385	349	1.04	0.69
Mu-Meter	8W1.1W	15:04:07	23.14	0.46	0.79	0.74	0.66	0.79	0.73				
Mu-Meter	9W1.1E	15:12:48	31.82	0.56	0.78	0.75							
Mu-Meter	10W1.1W	15:14:11	33.20	0.58	0.82	0.75							
Mu-Meter	11W1.1E	15:22:27	41.47	0.50	0.85	0.78							
Mu-Meter	12W1.1W	15:23:48	42.82	0.62	0.84	0.78							

WET-RUN TRACTION DATA FOR 0.20-INCH WATER DEPTH, ONE PASS

Date: 2/28/73
Test Area Identification: Taxiway 2
Test Section Bearing: 08/26
Wind Direction: 28°
Wind Velocity: 3 knots
Relative Humidity: 37%
Air Temperature: 54°F

1st Pass
Time In: 11:02:25
Time Out: 11:12:48
2nd Pass
Time In:
Time Out:
Zero Reference Time: t_{o_1} = 11:07:36

Weather: Fair & Clear
Asphalt Temperature: 50 to 76°F
Average Dry Coefficient of Friction
Entire Test Area: 0.85
DBV Strip: 0.80
Dry Stopping Distance: 336 ft

Test Vehicle	Test Run Identification	Clock Time (t_{f_1}), hr:min:sec	Elapsed Time (Δt_1), min	Mu-Meter Coefficient of Friction (μ_m)						DBV Data			
				Entire Test Area			DBV Test Strip						
				Min.	Max.	Integ. Avg.	Min.	Max.	Arith. Avg.	RSD, ft	CSD, ft	SDR	μ_c
DBV	1W1.2E									489	506	1.51	0.47
Mu-Meter	1W1.2E	11:12:18	4.70	0.14	0.74	0.52	0.48	0.74	0.61				
DBV	2W1.2W	11:17:53	10.28							431	431	1.28	0.56
Mu-Meter	2W1.2W	11:18:17	10.68	0.28	0.76	0.63	0.60	0.76	0.68				
DBV	3W1.2E	11:19:44	12.13							442	427	1.27	0.56
Mu-Meter	3W1.2E	11:20:45	13.15	0.20	0.78	0.69	0.62	0.77	0.70				
DBV	4W1.2W	11:22:37	15.02							376	389	1.16	0.62
Mu-Meter	4W1.2W	11:23:26	15.83	0.32	0.79	0.68	0.65	0.79	0.72				
DBV	5W1.2E	11:25:05	17.48							363	351	1.04	0.68
Mu-Meter	5W1.2E	11:26:57	19.35	0.26	0.80	0.68	0.63	0.79	0.71				
DBV	6W1.2W	11:27:13	19.62							368	356	1.06	0.67
Mu-Meter	6W1.2W	11:28:03	20.45	0.38	0.79	0.74	0.70	0.74	0.75				
DBV	7W1.2E	11:29:15	21.65							372	360	1.07	0.67
Mu-Meter	7W1.2E	11:30:22	22.93	0.42	0.80	0.76	0.68	0.79	0.74				
DBV	8W1.2W	11:31:23	23.78							333	322	0.96	0.74
Mu-Meter	8W1.2W	11:32:11	24.58	0.48	0.81	0.77	0.76	0.71	0.79				
DBV	9W1.2E	11:37:16	30.20							191	275	0.82	0.87
Mu-Meter	9W1.2E	11:38:41	31.08	0.47	0.80	0.82	0.70	0.76	0.73				
DBV	10W1.2W	11:41:12	33.60							406	335	1.00	0.72
Mu-Meter	10W1.2W	11:40:16	32.67	0.51	0.79	0.82	0.75	0.78	0.77				

WET-RUN TRACTION DATA FOR 0.30-INCH WATER DEPTH, ONE PASS

Date: 3/2/73
Test Area Identification: Taxiway 2
Test Section Bearing: 08/26
Wind Direction: 02°
Wind Velocity: 5 knots
Relative Humidity: 26%
Air Temperature: 59°F

1st Pass
Time In: 13:07:55
Time Out: 13:25:14
2nd Pass
Time In:
Time Out:
Zero Reference Time: t_{o_1} = 13:16:35

Weather: Fair & Clear
Asphalt Temperature: 54 to 75°F
Average Dry Coefficient of Friction
Entire Test Area: 0.84
DBV Strip: 0.78
Dry Stopping Distance: 336 ft

Test Vehicle	Test Run Identification	Clock Time (t_{f_1}), hr:min:sec	Elapsed Time (Δt_1), min	Mu-Meter Coefficient of Friction (μ_m)						DBV Data			
				Entire Test Area			DBV Test Strip						
				Min.	Max.	Integ. Avg.	Min.	Max.	Arith. Avg.	RSD, ft	CSD, ft	SDR	μ_c
DBV	1W1.3E									490	490	1.46	0.49
Mu-Meter	1W1.3E	13:25:33	8.96	0.08	0.74	0.52	0.30	0.71	0.51				
DBV	2W1.3W	13:28:37	12.03							392	419	1.25	0.57
Mu-Meter	2W1.3W	13:29:22	12.78	0.28	0.70	0.63	0.50	0.70	0.60				
DBV	3W1.3E	13:30:28	12.88							425	425	1.26	0.57
Mu-Meter	3W1.3E	13:31:23	14.80	0.14	0.72	0.63	0.28	0.72	0.50				
DBV	4W1.3W	13:32:17	15.70							427	400	1.19	0.60
Mu-Meter	4W1.3W	13:33:06	16.52	0.22	0.70	0.70	0.58	0.70	0.64				
DBV	5W1.3E	13:35:00	18.42							401	401	1.19	0.60
Mu-Meter	5W1.3E	13:34:57	18.37	0.26	0.71	0.65	0.56	0.70	0.63				
DBV	6W1.3W	13:36:02	19.45							404	404	1.20	0.60
Mu-Meter	6W1.3W	13:36:42	20.12	0.30	0.71	0.66	0.60	0.71	0.66				
DBV	7W1.3E	13:46:48	30.22							413	352	1.05	0.68
Mu-Meter	7W1.3E	13:47:52	31.28	0.37	0.72	0.71	0.64	0.78	0.71				
DBV	8W1.3W	13:48:56	32.35							433	358	1.07	0.67
Mu-Meter	8W1.3W	13:49:37	33.03	0.44	0.78	0.74	0.69	0.76	0.73				
Mu-Meter	9W1.3E	13:57:52	41.28	0.46	0.80	0.76	0.67	0.80	0.74				
Mu-Meter	10W1.3W	13:59:29	42.90	0.52	0.82	0.79	0.71	0.82	0.77				

WET-RUN TRACTION DATA FOR 0.05-INCH WATER DEPTH, TWO PASSES

Date: 2/28/73
Test Area Identification: Taxiway 2
Test Section Bearing: 08/26
Wind Direction: 29°
Wind Velocity: 13 knots
Relative Humidity: 19%
Air Temperature: 60°F

1st Pass
Time In: 13:23:24
Time Out: 13:24:40
2nd Pass
Time In: 13:29:27
Time Out: 13:30:49
Zero Reference Time: t_{o_2} = 13:30:08
t_{o_3} = 13:27:07

Weather: Fair & Clear
Asphalt Temperature: 50 to 76°F
Average Dry Coefficient of Friction
Entire Test Area: 0.87
DBV Strip: 0.81
Dry Stopping Distance: 336 ft

Test Vehicle	Test Run Identification	Clock Time (t_{f_2}, t_{f_3}), hr:min:sec	Elapsed Time, min		Mu-Meter Coefficient of Friction (μ_m)						DBV Data			
					Entire Test Area			DBV Test Strip						
			Δt_2	Δt_3	Min.	Max.	Integ. Avg.	Min.	Max.	Arith. Avg.	RSD, ft	CSD, ft	SDR	μ_c
DBV	1W2.05E										516	483	1.44	0.50
Mu-Meter	1W2.05E	13:32:17	2.15	5.17	0.40	0.69	0.56	0.54	0.69	0.62				
DBV	2W2.05W	13:34:23	4.25	7.27							416	430	1.28	0.56
Mu-Meter	2W2.05W	13:35:20	5.20	8.21	0.39	0.75	0.63	0.57	0.73	0.65				
DBV	3W2.05E	13:35:58	5.96	8.85							500	468	1.39	0.51
Mu-Meter	3W2.05E	13:36:45	6.61	9.63	0.52	0.76	0.66	0.62	0.76	0.69				
DBV	4W2.05W	13:37:30	7.36	10.38							403	417	1.24	0.58
Mu-Meter	4W2.05W	13:38:12	8.06	11.08	0.57	0.76	0.68	0.60	0.76	0.68				
DBV	5W2.05E	13:38:52	8.73	11.75							475	418	1.24	0.58
Mu-Meter	5W2.05E	13:39:39	9.51	12.53	0.56	0.77	0.70	0.62	0.77	0.70				
DBV	6W2.05W	13:40:24	10.26	13.28							408	408	1.21	0.59
Mu-Meter	6W2.05W	13:41:08	11.00	14.02	0.54	0.79	0.74	0.73	0.76	0.75				
DBV	7W2.05E	13:50:38	20.50	23.52							355	332	0.99	0.72
Mu-Meter	7W2.05E	13:51:40	21.53	24.55	0.66	0.79	0.77	0.66	0.78	0.72				
DBV	8W2.05W	13:52:28	22.33	25.35							360	348	1.04	0.69
Mu-Meter	8W2.05W	13:53:09	23.01	26.03	0.71	0.84	0.77	0.77	0.82	0.80				
Mu-Meter	9W2.05E	14:02:09	32.01	35.03										
Mu-Meter	10W2.05W	14:02:47	32.65	35.67	0.76	0.85	0.82							

WET-RUN TRACTION DATA FOR 0.10-INCH WATER DEPTH, TWO PASSES

Date: 3/1/73
Test Area Identification: Taxiway 2
Test Section Bearing: 08/26
Wind Direction: 30°
Wind Velocity: 8 to 15 knots
Relative Humidity: 55%
Air Temperature: 46°F

<u>1st Pass</u>
Time In: 09:40:05
Time Out: 09:42:53
<u>2nd Pass</u>
Time In: 09:46:33
Time Out: 09:49:14
Zero Reference Time: t_{o_2} = 09:47:54
t_{o_3} = 09:44:40

Weather: High Winds
Asphalt Temperature: 54 to 64°F
Average Dry Coefficient of Friction
Entire Test Area: 0.81
DBV Strip: 0.80
Dry Stopping Distance: 336 ft

Test Vehicle	Test Run Identification	Clock Time (t_{f_2}, t_{f_3}), hr:min:sec	Elapsed Time, min		Mu-Meter Coefficient of Friction (μ_m)						DBV Data			
					Entire Test Area			DBV Test Strip						
			Δt_2	Δt_3	Min.	Max.	Integ. Avg.	Min.	Max.	Arith. Avg.	RSD, ft	CSD, ft	SDR	μ_c
DBV	1W2.1E										478	462	1.38	0.52
Mu-Meter	1W2.1E	09:51:31	3.61	5.84	0.24	0.69	0.61	0.59	0.69	0.64				
DBV	2W2.1W	09:54:28	6.56	9.79							387	387	1.15	0.62
Mu-Meter	2W2.1W	09:55:19	7.41	10.64	0.35	0.77	0.63	0.66	0.77	0.72				
DBV	3W2.1E	09:57:04	9.16	12.39							428	428	1.27	0.56
Mu-Meter	3W2.1E	09:56:54	8.99	12.22	0.36	0.79	0.68	0.65	0.79	0.72				
DBV	4W2.1W	09:57:59	10.08	13.31							399	373	1.11	0.64
Mu-Meter	4W2.1W	09:58:43	10.81	14.04	0.40	0.79	0.72	0.72	0.79	0.76				
DBV	5W2.1E	09:59:26	11.53	14.76							384	359	1.07	0.67
Mu-Meter	5W2.1E	10:00:16	12.36	15.59	0.41	0.79	0.71	0.68	0.79	0.74				
DBV	6W2.1W	10:01:04	13.16	16.39							391	378	1.13	0.64
Mu-Meter	6W2.1W	10:01:48	13.89	17.12	0.58	0.79	0.75	0.70	0.79	0.75				
DBV	7W2.1E	10:08:16	20.36	23.59							366	343	1.02	0.70
Mu-Meter	7W2.1E	10:09:07	21.21	24.44	0.46	0.78	0.74	0.65	0.76	0.71				
DBV	8W2.1W	10:10:00	22.09	25.32							374	344	1.02	0.70
Mu-Meter	8W2.1W	10:10:44	22.83	26.06	0.58	0.78	0.74	0.71	0.78	0.75				
Mu-Meter	9W2.1E	10:19:04	31.16	34.39	0.59	0.78	0.80							
Mu-Meter	10W2.1W	10:20:36	32.69	35.92	0.40	0.77	0.76							
Mu-Meter	11W2.1E	10:28:38	40.73	43.96	0.61	0.82	0.74							
Mu-Meter	12W2.1W	10:30:47	42.88	46.11	0.67	0.81	0.76							

WET-RUN TRACTION DATA FOR 0.20-INCH WATER DEPTH, TWO PASSES

Date: 3/2/73
Test Area Identification: Taxiway 2
Test Section Bearing: 08/26
Wind Direction: 01°
Wind Velocity: 10 knots
Relative Humidity: 61%
Air Temperature: 43°F

1st Pass
Time In: 08:42:51
Time Out: 08:48:08
2nd Pass
Time In: 08:50:14
Time Out: 08:55:43
Zero Reference Time: t_{o_2} = 08:52:59
t_{o_3} = 08:49:17

Weather: Fair & Clear
Asphalt Temperature: 54 to 75°F
Average Dry Coefficient of Friction
Entire Test Area: 0.81
DBV Strip: 0.82
Dry Stopping Distance: 336 ft

Test Vehicle	Test Run Identification	Clock Time (t_{f_2}, t_{f_3}), hr:min:sec	Elapsed Time, min		Mu-Meter Coefficient of Friction (μ_m)						DBV Data			
					Entire Test Area			DBV Test Strip						
			Δt_2	Δt_3	Min.	Max.	Intog. Avg.	Min.	Max.	Arith. Avg.	RSD, ft	CSD, ft	SDR	μ_c
DBV	1W2.2E										590	571	1.70	0.42
Mu-Meter	1W2.2E	08:55:34	2.58	6.28	0.22	0.68	0.58	0.52	0.68	0.60				
DBV	2W2.2W	08:57:49	4.84	8.54							505	458	1.36	0.52
Mu-Meter	2W2.2W	08:58:45	5.60	9.30	0.32	0.74	0.66	0.60	0.69	0.65				
DBV	3W2.2E	08:59:29	6.55	10.25							489	458	1.36	0.52
Mu-Meter	3W2.2E	09:00:24	7.42	11.12	0.34	0.74	0.68	0.57	0.74	0.66				
DBV	4W2.2W	09:01:08	8.15	11.85							489	444	1.32	0.54
Mu-Meter	4W2.2W	09:01:57	8.97	12.67	0.38	0.73	0.67	0.62	0.72	0.67				
DBV	5W2.2E	09:02:43	9.74	13.44							412	426	1.27	0.57
Mu-Meter	5W2.2E	09:03:35	10.60	14.30	0.42	0.75	0.70	0.60	0.75	0.68				
DBV	6W2.2W	09:04:19	11.32	15.02							435	435	1.29	0.55
Mu-Meter	6W2.2W	09:05:05	12.10	15.80	0.44	0.75	0.70	0.66	0.75	0.71				
DBV	7W2.2E	09:13:13	20.22	23.92							415	401	1.19	0.60
Mu-Meter	7W2.2E	09:14:04	21.09	24.79	0.34	0.76	0.76	0.62	0.76	0.69				
DBV	8W2.2W	09:14:47	21.80	25.50							423	409	1.22	0.59
Mu-Meter	8W2.2W	09:15:31	22.54	26.24	0.47	0.79	0.79	0.75	0.78	0.77				
Mu-Meter	9W2.2E	09:23:41	30.70	34.40										
Mu-Meter	10W2.2W	09:25:19	32.38	36.08	0.52	0.79	0.80							
Mu-Meter	11W2.2E	09:33:41	40.70	44.40	0.48	0.76	0.81							
Mu-Meter	12W2.2W	09:35:24	42.42	46.12	0.58	0.77	0.79							

WET-RUN TRACTION DATA FOR 0.30-INCH WATER DEPTH, TWO PASSES

Date: 3/2/73
Test Area Identification: Taxiway 2
Test Section Bearing: 08/26
Wind Direction: 27°
Wind Velocity: 6 knots
Relative Humidity: 43%
Air Temperature: 52°F

1st Pass
Time In: 10:24:47
Time Out: 10:33:06
2nd Pass
Time In: 10:38:33
Time Out: 10:46:28
Zero Reference Time: t_{o_2} = 10:42:36
t_{o_3} = 10:35:43

Weather: Fair & Clear
Asphalt Temperature: 54 to 75°F
Average Dry Coefficient of Friction
Entire Test Area: 0.81
DBV Strip: 0.80
Dry Stopping Distance: 336 ft

Test Vehicle	Test Run Identification	Clock Time (t_{f_2}, t_{f_3}), hr:min:sec	Elapsed Time, min		Mu-Meter Coefficient of Friction (μ_m)						DBV Data			
					Entire Test Area			DBV Test Strip						
			Δt_2	Δt_3	Min.	Max.	Integ. Avg.	Min.	Max.	Arith. Avg.	RSD, ft	CSD, ft	SDR	μ_c
DBV	1W2.3E										567	531	1.58	0.45
Mu-Meter	1W2.3E	10:48:04	5.47	12.35	0.14	0.69	0.57	0.45	0.69	0.57				
DBV	2W2.3W	10:48:56	6.33	13.21							492	461	1.37	0.52
Mu-Meter	2W2.3W	10:49:47	7.18	14.06	0.29	0.78	0.61	0.54	0.78	0.66				
DBV	3W2.3E	10:50:31	7.92	14.80							466	466	1.39	0.51
Mu-Meter	3W2.3E	10:51:26	8.83	15.71	0.22	0.71	0.63	0.55	0.71	0.63				
DBV	4W2.3W	10:52:07	9.52	16.40							510	448	1.33	0.54
Mu-Meter	4W2.3W	10:52:45	10.15	17.03	0.32	0.71	0.67	0.58	0.71	0.65				
DBV	5W2.3E	10:53:34	10.97	17.85							513	451	1.34	0.53
Mu-Meter	5W2.3E	10:54:24	11.80	18.68	0.30	0.74	0.66	0.52	0.74	0.63				
DBV	6W2.3W	10:55:05	12.48	19.36							428	401	1.19	0.60
Mu-Meter	6W2.3W	10:55:43	13.12	20.00	0.36	0.74	0.68	0.63	0.74	0.69				
DBV	7W2.3E	11:02:37	20.02	26.90							476	418	1.24	0.58
Mu-Meter	7W2.3E	11:03:24	20.80	27.68	0.38	0.74	0.72	0.60	0.73	0.67				
DBV	8W2.3W	11:04:05	21.48	28.36							419	392	1.17	0.61
Mu-Meter	8W2.3W	11:04:45	22.15	29.03	0.42	0.75	0.74	0.71	0.77	0.74				
DBV	9W2.3E	11:12:29	29.88	36.76							413	375	1.12	0.64
Mu-Meter	9W2.3E	11:13:13	30.48	37.36	0.37	0.74	0.74	0.62	0.73	0.68				
DBV	10W2.3W	11:13:57	31.35	38.23							426	399	1.19	0.60
Mu-Meter	10W2.3W	11:14:37	32.02	38.90	0.47	0.74	0.75	0.66	0.74	0.70				

APPENDIX II

WATER-DEPTH DATA FOR STATION 1

(February 27 through March 2, 1973)

WATER-DEPTH DATA FOR 0.05 INCH OF WATER
APPLIED IN ONE PASS

Date: 2/28/73
Zero Reference Time: t_{o_1} = 09:06:18

Clock Time, hr:min:sec	Elapsed Time (Δt_1), min	Average Water Depth, in.
09:07:40	1.37	0.04
09:10:55	4.62	0.05
09:12:30	6.20	0.04
09:14:24	8.10	0.03
09:15:20	9.03	0.03
09:15:47	9.48	0.03
09:16:10	9.87	0.02
09:16:48	10.50	0.03
09:17:27	11.15	0.03
09:17:45	11.45	0.02
09:18:15	11.95	0.01
09:19:07	12.82	0.01
09:19:50	13.53	0.02
09:24:47	18.48	0.02
09:25:24	19.10	0.01
09:26:03	19.75	0.01
09:27:42	21.40	0.00

WATER-DEPTH DATA FOR 0.10 INCH OF WATER APPLIED IN ONE PASS

Date: 2/27/73
Zero Reference Time: t_{o_1} = 14:40:59

Clock Time, hr:min:sec	Elapsed Time (Δt_1), min	Average Water Depth, in.
14:43:04	2.08	0.03
14:44:53	3.90	0.03
14:47:06	6.12	0.03
14:48:11	7.20	0.03
14:49:44	8.75	0.03
14:50:52	9.88	0.03
14:51:49	10.83	0.03
14:52:46	11.78	0.03
14:53:20	12.35	0.03
14:54:16	13.28	0.03
14:54:55	13.93	0.03
14:55:07	14.13	0.03
15:01:10	20.18	0.03
15:02:30	21.52	0.03
15:03:35	22.60	0.01
15:05:31	24.53	0.02

WATER-DEPTH DATA FOR 0.20 INCH OF WATER
APPLIED IN ONE PASS

Date: 2/28/73
Zero Reference Time: t_{o_1} = 11:07:36

Clock Time, hr:min:sec	Elapsed Time (Δt_1), min	Average Water Depth, in.
11:08:29	0.88	0.02
11:13:00	5.40	0.03
11:14:16	6.67	0.03
11:15:21	7.75	0.03
11:16:05	8.48	0.02
11:17:45	10.15	0.02
11:18:28	10.87	0.02
11:19:41	12.08	0.02
11:20:23	12.78	0.01
11:21:34	13.97	0.01
11:22:12	14.60	0.00

WATER-DEPTH DATA FOR 0.30 INCH OF WATER
APPLIED IN ONE PASS

Date: 3/2/73 Zero Reference Time: t_{o_1} = 13:16:35		
Clock Time, hr:min:sec	Elapsed Time (Δt_1), min	Average Water Depth, in.
13:17:31	0.93	0.04
13:25:00	8.42	0.02
13:28:05	11.50	0.03
13:28:49	12.23	0.03
13:29:40	13.08	0.02
13:30:23	13.80	0.02
13:31:13	14.63	0.01
13:32:06	15.52	0.02
13:32:47	16.20	0.01
13:33:29	16.90	0.01
13:34:42	18.12	0.01

WATER-DEPTH DATA FOR 0.05 INCH OF WATER
APPLIED IN TWO PASSES

Date: 2/28/73
Zero Reference Time: t_{o_2} = 13:30:08
t_{o_3} = 13:27:07

Clock Time, hr:min:sec	Elapsed Time, min		Average Water Depth, in.
	Δt_2	Δt_3	
13:30:30	0.37	3.38	0.04
13:32:08	2.00	5.02	0.04
13:34:24	4.27	7.28	0.02
13:35:27	5.32	8.33	0.02
13:35:53	5.75	8.77	0.03
13:36:35	6.45	9.47	0.02
13:37:31	7.38	10.40	0.02
13:38:19	8.18	11.20	0.03
13:38:50	8.70	11.72	0.02
13:39:30	9.37	12.38	0.02
13:40:30	10.37	13.38	0.03
13:41:15	11.12	14.13	0.01

WATER-DEPTH DATA FOR 0.10 INCH OF WATER
APPLIED IN TWO PASSES

Date: 3/1/73
Zero Reference Time: t_{o_2} = 09:47:54
t_{o_3} = 09:44:40

Clock Time, hr:min:sec	Elapsed Time, min		Average Water Depth, in.
	Δt_2	Δt_3	
09:54:10	6.26	9.49	0.03
09:55:10	7.26	10.49	0.03
09:58:16	10.37	13.60	0.02
09:59:14	11.33	14.56	0.02
10:00:40	12.77	16.00	0.02
10:01:30	13.60	16.83	0.02
10:02:04	14.17	17.40	0.02
10:03:37	15.72	18.95	0.02
10:04:12	16.30	19.53	0.01
10:04:50	16.93	20.16	0.01
10:05:52	17.98	21.21	0.01
10:06:44	18.83	22.06	0.01
10:12:05	24.18	27.41	0.01
10:13:40	25.77	29.00	0.00

WATER-DEPTH DATA FOR 0.20 INCH OF WATER
APPLIED IN TWO PASSES

Date: 3/2/73
Zero Reference Time: t_{o_2} = 08:52:59
t_{o_3} = 08:49:17

Clock Time, hr:min:sec	Elapsed Time, min		Average Water Depth, in.
	Δt_2	Δt_3	
08:55:19	2.33	6.03	0.03
08:57:43	4.73	8.43	0.02
08:58:45	5.77	9.47	0.02
08:59:19	6.33	10.03	0.02
09:00:08	7.15	10.85	0.02
09:01:00	8.02	11.72	0.02
09:01:57	8.97	12.67	0.03
09:02:33	9.57	13.27	0.02
09:03:19	10.33	14.03	0.03
09:04:12	11.22	14.92	0.03
09:05:04	12.08	15.78	0.02
09:13:02	20.05	23.75	0.02
09:13:46	20.78	24.48	0.02
09:14:39	21.67	25.37	0.01
09:15:30	22.52	26.22	0.00

WATER-DEPTH DATA FOR 0.30 INCH OF WATER
APPLIED IN TWO PASSES

Date: 3/2/73
Zero Reference Time: t_{o_2} = 10:42:36
t_{o_3} = 10:35:43

Clock Time, hr:min:sec	Elapsed Time, min		Average Water Depth, in.
	Δt_2	Δt_3	
10:42:55	0.32	7.20	0.03
10:46:43	4.12	11.00	0.03
10:48:44	6.13	13.01	0.03
10:49:37	7.02	13.90	0.03
10:50:11	7.58	14.46	0.02
10:51:00	8.40	15.28	0.02
10:51:47	9.18	16.06	0.03
10:52:34	9.97	16.85	0.02
10:53:12	10.60	17.48	0.02
10:53:50	11.23	18.11	0.03
10:54:40	12.07	18.95	0.03
10:55:27	12.85	19.73	0.03
11:02:00	19.40	26.28	0.01
11:02:40	20.07	26.95	0.01
11:03:30	20.90	27.78	0.02
11:04:15	21.65	28.53	0.01
11:10:43	28.12	35.00	0.00

APPENDIX III

REPEAT WET-RUN TRACTION DATA

(September 27, 1973)

REPEAT WET-RUN TRACTION DATA FOR 0.20-INCH WATER DEPTH, ONE PASS

Date: 9/27/73
Test Area Identification: Taxiway 2
Test Section Bearing: 08/26
Wind Direction: 26°
Wind Velocity: 3 knots
Relative Humidity: 38%
Air Temperature: 60°F

<u>1st Pass</u>
Time In: 10:27:08
Time Out: 10:36:30
<u>2nd Pass</u>
Time In:
Time Out:
Zero Reference Time: t_{o_1} = 10:31:49

Weather: Clear
Asphalt Temperature:
Average Dry Coefficient of Friction
Entire Test Area: 0.78
DBV Strip:
Dry Stopping Distance:

Test Vehicle	Test Run Identification	Clock Time (t_{f_1}), hr:min:sec	Elapsed Time (Δt_1), min	Mu-Meter Coefficient of Friction (μ_m)						DBV Data			
				Entire Test Area			DBV Test Strip						
				Min.	Max.	Integ. Avg.	Min.	Max.	Arith. Avg.	RSD, ft	CSD, ft	SDR	μ_c
Mu-Meter	1W1.2E	10:36:34	4.75	0.27	0.69	0.55	0.31	0.69	0.53				
Mu-Meter	2W1.2W	10:38:02	6.22	0.33	0.71	0.59	0.62	0.70	0.67				
Mu-Meter	3W1.2E	10:39:54	8.08	0.31	0.73	0.61	0.62	0.73	0.66				
Mu-Meter	4W1.2W	10:41:25	9.60	0.40	0.72	0.63	0.66	0.72	0.69				
Mu-Meter	5W1.2E	10:43:26	11.61	0.34	0.72	0.65	0.63	0.72	0.68				
Mu-Meter	6W1.2W	10:45:02	13.22	0.44	0.72	0.67	0.68	0.72	0.70				
Mu-Meter	7W1.2E	10:52:03	20.23	0.48	0.72	0.69	0.48	0.72	0.64				
Mu-Meter	8W1.2W	10:53:54	22.08	0.54	0.73	0.69	0.72	0.70	0.71				
Mu-Meter	9W1.2E	11:02:01	30.20	0.57	0.70	0.68	0.69	0.70	0.70				
Mu-Meter	10W1.2W	11:03:59	32.17	0.63	0.74	0.70	0.70	0.74	0.72				

REPEAT WET-RUN TRACTION DATA FOR 0.20-INCH WATER DEPTH, TWO PASSES

Date: 9/27/73
Test Area Identification: Taxiway 2
Test Section Bearing: 08/26
Wind Direction: 26°
Wind Velocity: 3 knots
Relative Humidity: 38%
Air Temperature: 60°F

1st Pass
Time In: 11:17:16
Time Out: 11:21:28
2nd Pass
Time In: 11:25:20
Time Out: 11:30:10
Zero Reference Time: t_{o_2} = 11:27:45
t_{o_3} = 11:23:45

Weather: Clear
Asphalt Temperature:
Average Dry Coefficient of Friction
Entire Test Area: 0.78
DBV Strip:
Dry Stopping Distance:

Test Vehicle	Test Run Identification	Clock Time (t_{f_1}), hr:min:sec	Elapsed Time, min		Mu-Meter Coefficient of Friction (μ_m)						DBV Data			
					Entire Test Area			DBV Test Strip						
			Δt_2	Δt_3	Min.	Max.	Integ. Avg.	Min.	Max.	Arith. Avg.	RSD, ft	CSD, ft	SDR	μ_c
Mu-Meter	1W2.2E	11:30:25	2.67	6.70	0.21	0.59	0.43	0.47	0.58	0.53				
Mu-Meter	2W2.2W	11:32:02	4.28	8.31	0.31	0.65	0.53	0.46	0.64	0.57				
Mu-Meter	3W2.2E	11:33:50	6.08	10.11	0.25	0.66	0.57	0.29	0.66	0.52				
Mu-Meter	4W2.2W	11:35:32	7.78	11.81	0.34	0.66	0.61	0.50	0.66	0.60				
Mu-Meter	5W2.2E	11:37:15	9.50	13.53	0.31	0.70	0.58	0.53	0.70	0.60				
Mu-Meter	6W2.2W	11:38:53	11.13	15.16	0.40	0.70	0.65	0.60	0.70	0.66				
Mu-Meter	7W2.2E	11:47:55	20.17	24.20	0.46	0.70	0.66	0.46	0.70	0.63				
Mu-Meter	8W2.2W	11:49:27	21.70	25.73	0.48	0.70	0.69	0.68	0.69	0.68				
Mu-Meter	9W2.2E	11:58:01	30.27	34.30	0.54	0.71	0.69	0.68	0.70	0.69				
Mu-Meter	10W2.2W	11:59:45	32.00	36.03	0.58	0.72	0.68	0.69	0.70	0.70				

APPENDIX IV

REPEAT WATER-DEPTH DATA FOR STATION 1
(September 27, 1973)

REPEAT WATER-DEPTH DATA FOR 0.20 INCH OF WATER APPLIED IN ONE PASS

Date: 9/27/73
Zero Reference Time: t_{o_1} = 10:31:49

Clock Time, hr:min:sec	Elapsed Time (Δt_1), min	Average Water Depth, in.
10:36:30	4.68	0.05
10:38:51	7.03	0.02
10:40:07	8.30	0.01
10:41:53	11.07	0.01
10:43:46	11.95	0.01
10:52:31	20.70	0.00

REPEAT WATER-DEPTH DATA FOR 0.20 INCH OF WATER APPLIED IN TWO PASSES

Date: 9/27/73
Zero Reference Time: t_{o_2} = 11:27:45
t_{o_3} = 11:23:43

Clock Time, hr:min:sec	Elapsed Time, min		Average Water Depth, in.
	Δt_2	Δt_3	
11:29:54	2.15	6.18	0.04
11:31:47	4.03	8.06	0.02
11:33:19	5.57	9.60	0.02
11:35:17	7.33	11.36	0.01
11:36:47	9.03	13.06	0.00
11:38:37	10.87	14.90	0.00

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5 December 1974

ERRATA

AFWL-TR-74-152 INFLUENCE OF WATER DEPTH ON TRACTION CHARACTERISTICS OF ASPHALT CONCRETE PAVEMENTS, November 1974 (UNCLASSIFIED)

Pages 10, 15, and 34 Replace with corrected pages

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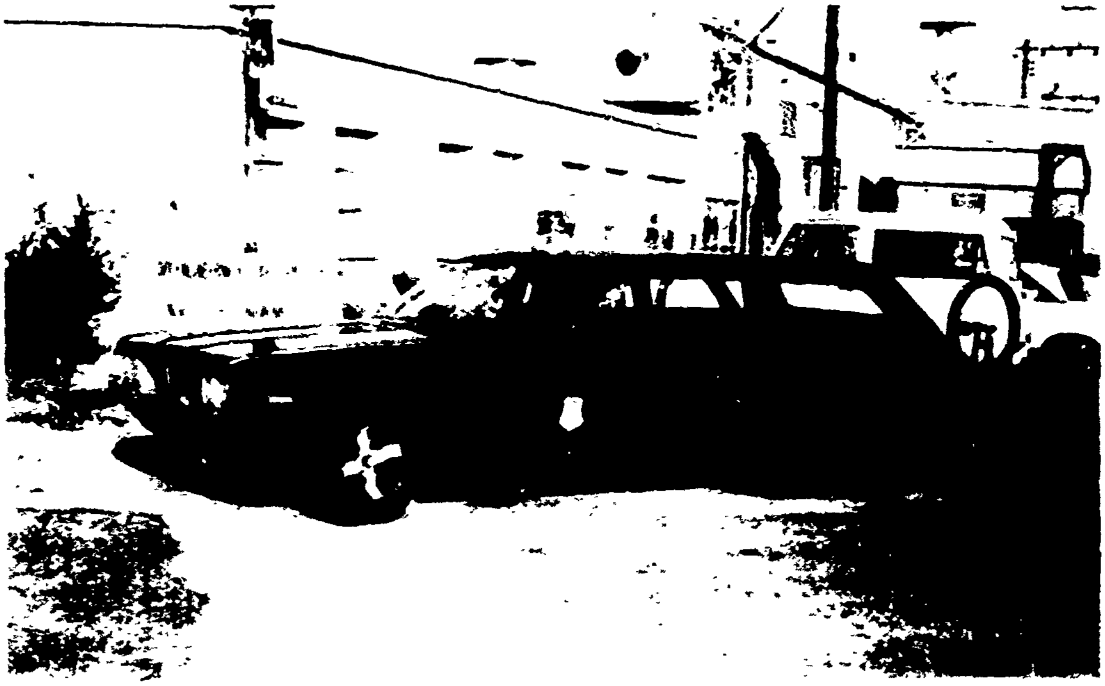

Figure 4. Diagonally Braked Vehicle

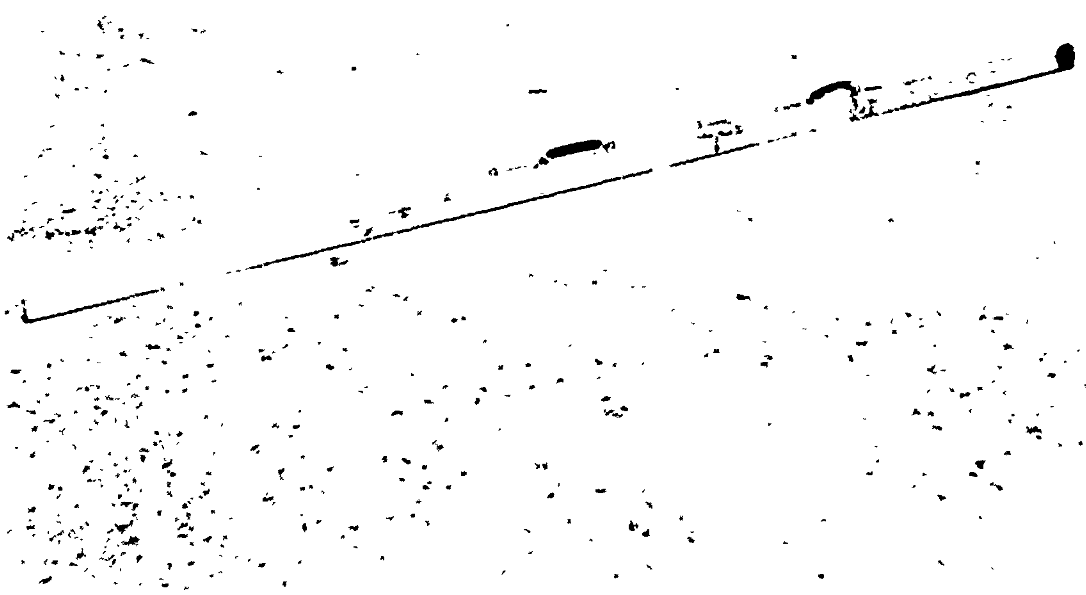

Figure 5. Cross-Slope Measuring Device

5. WATER-FILM DEPTH GAGE

The water-film depth gage used in this study (fig. 6) was developed by NASA to rapidly measure water-film depth on highway and airfield pavement surfaces. This water-film depth gage consists of a plastic disc 5 in. in diameter supported by three metal prongs 15/16 in. long. Plexiglas rods of different lengths are attached to the bottom side of the circular plastic disc. These rods are adjusted so that their tips are located between 0.01 and 0.10 in. above the plane defined by the tips of the metal prongs. The upper tips of the Plexiglas rods are marked to indicate the actual gap between the plane passing through the tips of the prongs and the bottom of each individual rod. Since water is a light-reflecting substance, it reflects more light than the runway surface and, consequently, the tips of the rods that are not in contact with the water appear lighter than those that are touching or submerged in the water. From the rods that appear dark, the one that has the highest reading on the scale determines the water-film depth at that particular location. For instance, in figure 6 the water depth is approximately 0.06 in.

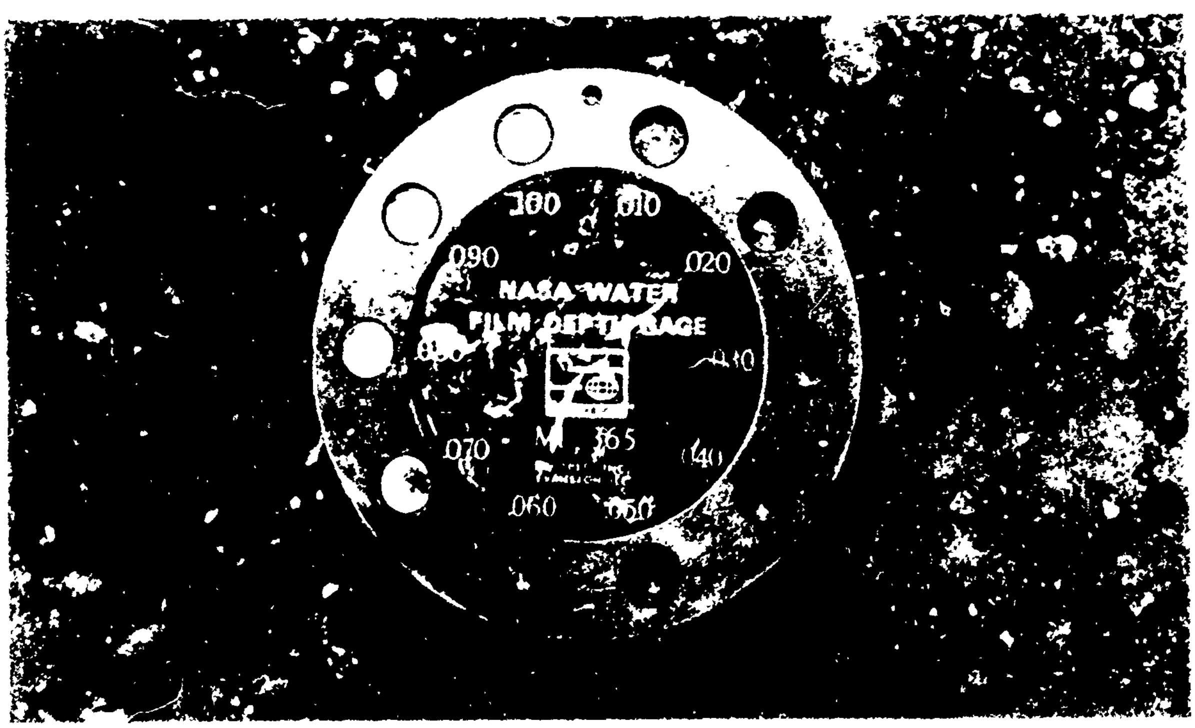

Figure 6. NASA Water-Film Depth Gage

Examination of figures 7 through 10 reveals that for any given water depth, the single-pass application invariably creates the worst traction characteristics early after wetting (within 15 minutes). However, for any given amount of applied water the double-pass application does not yield radically different friction-recovery characteristics provided that the elapsed time after wetting is interpreted according to time interval Δt_3. These figures clearly indicate that for double-pass application of any given water depth, interpretation of the elapsed time after wetting according to time interval Δt_2 causes the shifting of the friction-recovery curve too far to the left, thus yielding high coefficients of friction at relatively early times. At late times (in excess of 15 minutes), all three methods of zero reference time interpretation yield comparable data which in general lie within the domain of the experimental data spread.

The reason a given amount of water was applied in two passes was as follows. It was assumed that the first half of the water would fill the pores and irregularities in the pavement surface, while the second half would provide as much free-floating water as possible to create an adverse pavement traction condition. As can be seen in figures 7 through 10, the time interval between water application and the initial vehicular measurement is a minimum when Δt_2 is used as the elapsed time. However figures 7 through 10 also show that the first data point for a single wetting pass, Δt_1, or for double application using Δt_3 as the elapsed time interval is at least 7 minutes after wetting. While it is not the intent to arbitrarily pick a method of computing a zero water reference time that will allow a small time interval after wetting, a method is necessary that does not require extrapolation of the data for long time intervals; therefore, the various application rates and time calculations were analyzed to see if a more severe wet condition could be obtained for use in the standard AFWL test procedure. To portray the influence of the recovery rate of the coefficient of friction as a function of applied water depth, the data from figures 7 through 10 were rearranged for one and two pass applications in figures 11 and 12 respectively.

It can be noted on figures 11 and 12 that the initial coefficient of friction measured by the Mu-Meter is essentially the same regardless of wetting technique or method of calculating the zero water time. The data confirm the difference in recovery rates (improved friction) for the various water volumes applied. The more water applied the longer the drainage period for a return to a dry condition. However, the data is insufficient to conclude that if 0.30 inch of water is applied the recovery curve can be extrapolated back to the 3 minute point, which is currently the first data point in the standard AFWL skid resistance test.

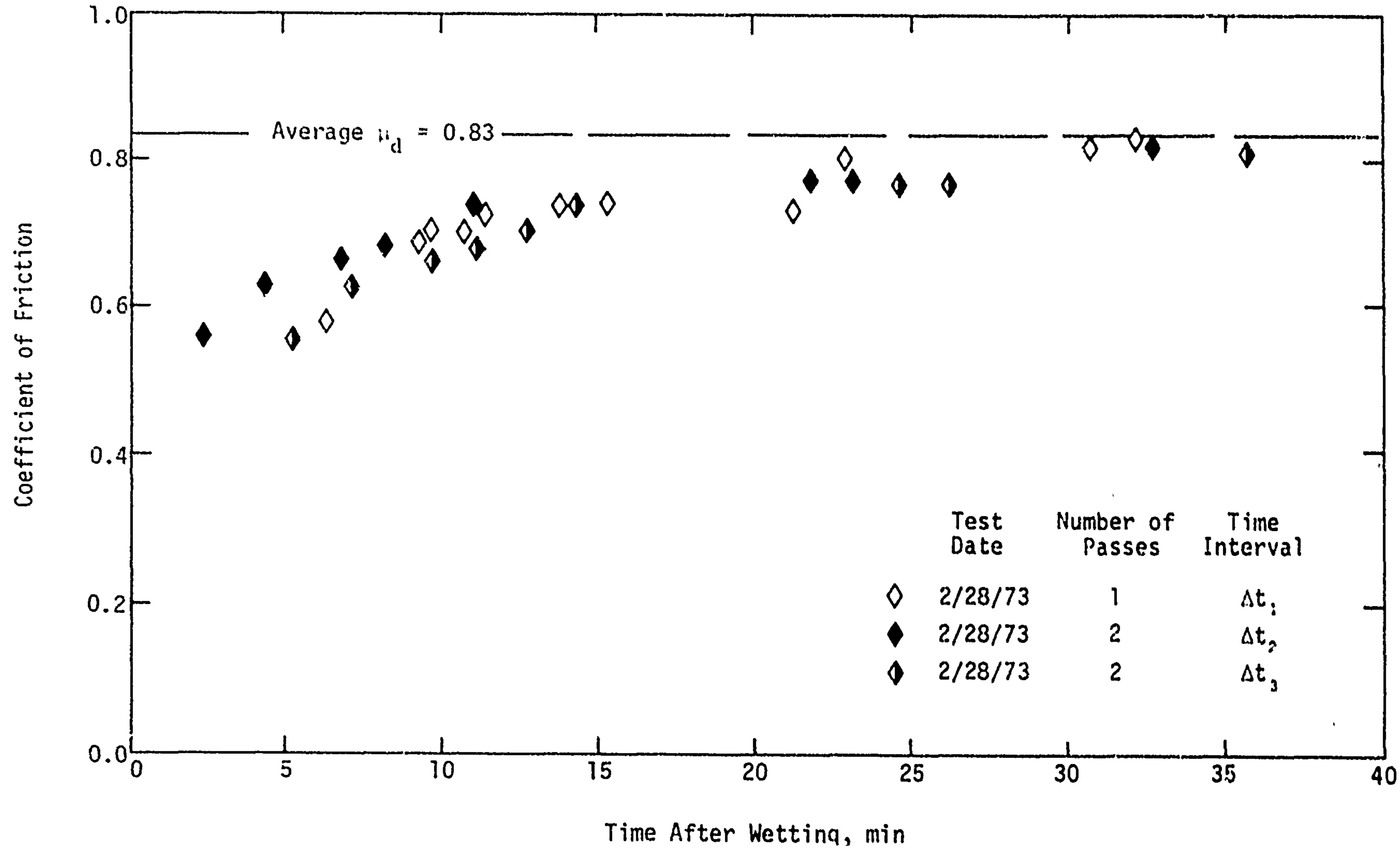

Figure 7. Coefficient of Friction versus Time After Wetting for 0.05-Inch Water Depth (Entire Test Area)

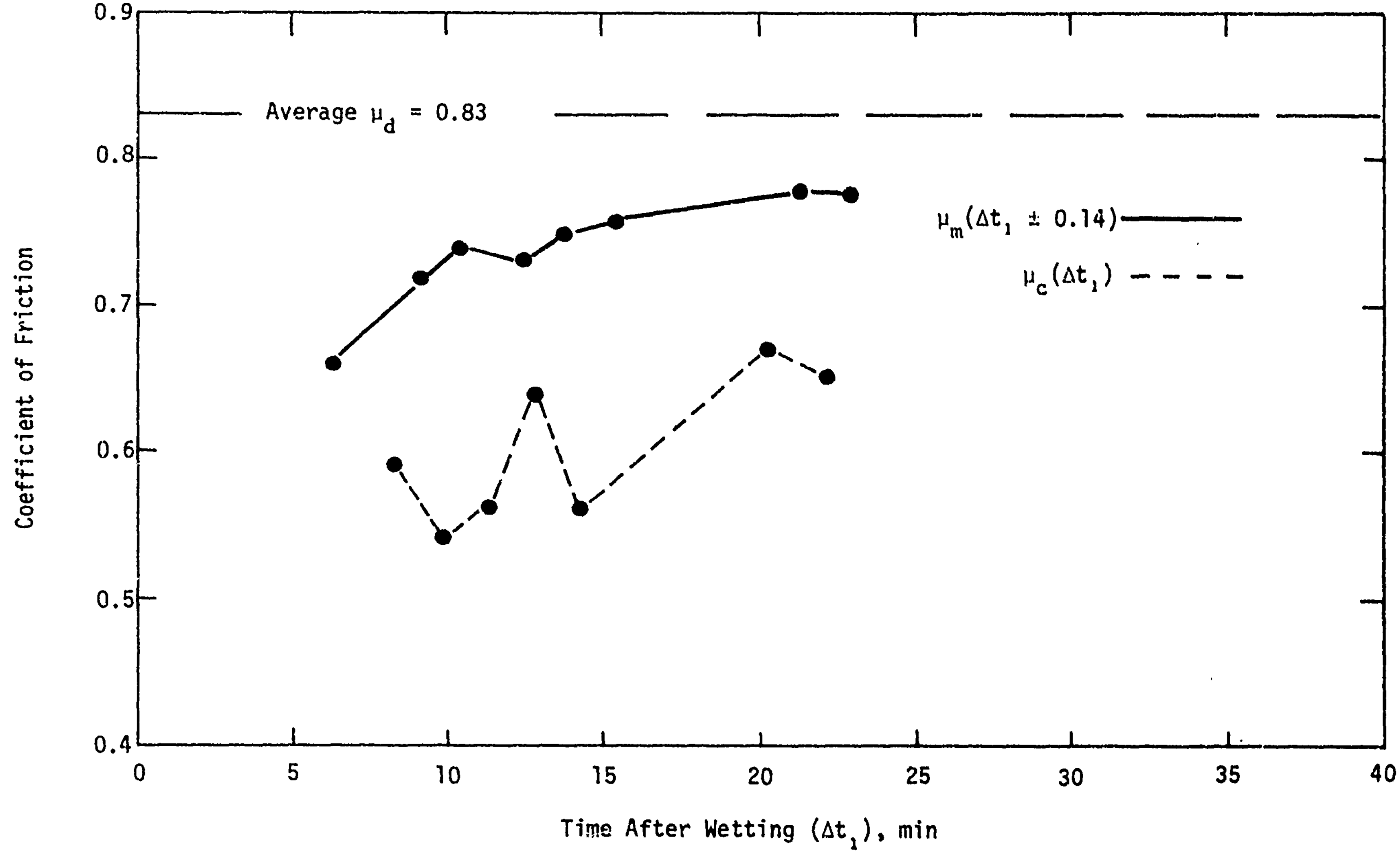

Figure 19. Comparison of Coefficients of Friction Measured by Mu-Meter and Calculated from DBV Data versus Time After Wetting for 0.05-Inch Water Depth Applied in One Pass (DBV Test Strip)

Figure 20 presents the data for the 0.20-inch water depth applied in two passes. The corrected time after wetting for the Mu-Meter data in this case was Δt_2 = 0.14 minutes. From figures 19 and 20 it is evident that the coefficients of friction measured by the Mu-Meter were not seriously influenced by directional effects. Some indications of directional effects may be shown by the wider scatter of the DBV calculated Mu-Meter values. The DBV has shown from previous testing to have a somewhat wider data scatter than the Mu-Meter, and this fact may also have an influence on the calculated friction valves.

6. REPEATABILITY OF TRACTION DATA

The traction and water-depth test data presented in appendix I and II, respectively, were gathered between February 27 and March 2, 1973. Since repeatability of pavement traction data was of interest, tests involving the 0.20-inch water depth applied in one and two passes were repeated on September 27, 1973. A DBV was not available at this time; therefore, the data were limited to Mu-Meter measurements of the entire test area (appendix III) and water-depth measurements at station 1 (appendix IV).

Figure 21 shows average coefficients of friction for the entire test area versus time after wetting. The time after wetting was interpreted as Δt_1 for a single application of 0.20 inch of water, and both as Δt_2 and Δt_3 when the 0.20 inch of water was applied in two passes.

Comparison of figure 21 and figure 9 reveals that in general the data in figure 21 exhibit a slower rate of friction recovery. The variation of the data is less pronounced at early times after wetting (0 to 15 minutes), but somewhat more pronounced beyond 15 minutes. The data variation, although not significant for the time interval after 15 minutes may be attributed to the different environmental conditions affecting the evaporation and drainage; however, the critical time period for pavement traction evaluation is 3 to 15 minutes after wetting. Comparison of figure 21 with either or both figures 11 and 12 indicates that the data of figure 21 fall within upper and lower boundaries of figures 11 and 12, which ascertains the fair degree of repeatability of the test data.

Figure 22 shows the water-depth data for station 1 as a function of time after wetting, interpreted both as Δt_1 and Δt_3. These data show a more consistent trend than the water-depth data in figure 18. In view of the inherent drawbacks and the lack of sensitivity of the water-film depth gage, no attempt